DOCUMENT RESUME

ED 286 719	SE 048 377

TITLE	Math Space Mission. [A Product of] the Regional Math Network: A Teacher Invigoration and Curriculum Development Project.
INSTITUTION	Harvard Univ., Cambridge, Mass. Graduate School of Education.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	Jun 87
GRANT	NSF-MDR-84-70399
NOTE	322p.; For other products of the Regional Math Network, see SE 048 378-379.
AVAILABLE FROM	Dale Seymour Publications, P.O. Box 10888, Palo Alto, CA 94303 ($35.00; includes Fact Book and Problem Deck).
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052) -- Guides - Classroom Use - Materials (For Learner) (051) -- Tests/Evaluation Instruments (160)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Astronomy; *Estimation (Mathematics); Geometric Concepts; Geometry; Mathematical Applications; Mathematical Concepts; *Mathematical Enrichment; Mathematics Education; *Mathematics Instruction; Mathematics Skills; Problem Solving; Ratios (Mathematics); Science Education; Science Instruction; Secondary Education; *Secondary School Mathematics; Secondary School Science; Space Exploration; Space Sciences
IDENTIFIERS	Graphing (Mathematics)

ABSTRACT

This unit is intended to teach estimation skills in such a way as to be relevant and useful to students as they apply them in various problem-solving activities. The teaching activities feature the earth, exploration into space, and the other worlds in the solar system. The teacher's guide contains four modules. Module I suggests the use of several multi-media experiences to set the stage for the activities that follow. Module II, "The Solar System," incorporates teaching activities dealing with rounding numbers, estimation of sums, differences, products and quotients, graphing, and the application of these skills in problem solving. Module III, "The Space Shuttle," addresses the use of the space shuttle and stresses the mathematical concepts of ratio and proportion. Module IV, "The Space Colony," uses geometric concepts as students build a three-dimensional living space colony. The entire unit includes teacher notes, student worksheets, answer sheets, activity cards, transparency masters, and classroom games. It also contains a "Math Space Mission Fact Book," an annotated bibliography, and a "Math/Space Mission Problem Deck" (of card) for students. A "Solar System Planet Card Deck" is not included here insofar as it is duplicated in the "Math Space Mission Fact Book". (TW)

ED286719

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it

☐ Minor changes have been made to improve reproduction quality

- Points of view or opinions stated in this document do not necessarily represent official OERI position or policy

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY
Beverly Cory
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

MATH SPACE MISSION

THE REGIONAL
MATH
NETWORK

A Teacher Invigoration and Curriculum Development Project
sponsored by the
National Science Foundation
and
Harvard Graduate School of Education

SE 048 377

BEST COPY AVAILABLE

This set of student materials and teacher notes is published and distributed by the Regional Math Network at the Harvard Graduate School of Education. Permission is granted to the teacher who purchases or receives this book to reproduce the materials for use with his or her students.

This material is based upon work supported by the National Science Foundation under Grant No. MDR-84-70399.

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation.

© 1987 President and Fellows of Harvard College
Harvard Graduate School of Education
All Rights Reserve

REGIONAL MATH NETWORK

DIRECTOR
Katherine K. Merseth

ASSOCIATE DIRECTOR FOR STAFF DEVELOPMENT
Joan Karp

ASSOCIATE DIRECTOR FOR PRODUCTION
Winifred Covintree

TEAM LEADERS

Ann Grady	Quincy Market
Dorothy Galo	Sports Shorts
Maria Marolda	Math /Space Mission
Anne Smith	Ice Cream
Lisa Oray	Staff Assistant
Winifred Covintree	Graphic Artist

TEACHER FELLOWS

Lee Bevilaqua	Archdiocese of Boston
Ann Cook	Tower School
Elizabeth Culbert	Hingham
Lisa Dahill	Carroll School
Sister Catherine Decker	Archdiocese of Boston
Leda Drouin	Chelmsford
Judy Fields	Boston
Jean Foley	Somerville
Sonia Harvey	Boston
Richard Horner	Boston
Ellen Kreopolides	Waltham
A. William Larson	Hingham
Patricia Maloney	Waltham
Judith McKendry	Acton
Evagrio Mosca	Lexington
Leah Muth	Archdiocese of Boston
George Perry	Boston
Yolanda Rodriguez	Cambridge
Edith Sparre	Lexington
Dorothy Walsh	Cambridge
Judith White	Chelmsford
Thomas Zaya	Somerville

EVALUATION CONSULTANTS

Hyoshin Kim and Barbara Neufeld of
Education Matters, Inc.

Acknowledgements

We would like to acknowledge the contributions that several people have made to the development of these materials and to the overall implementation of the project.

For their presentations to the Teacher Fellows and project staff and for their helpful comments on the direction of The Regional Math Network activities, special gratitude is due to:

Stanley Bezuszka
Patricia Davidson
Carole Greenes
Michael Guillen
Peter Hilton
Alan Hoffer
Deborah Hughes-Hallett
Margaret Kenney
Steven Leinwand
Henry Pollak
Judah Schwartz
Harold Weymouth

The following individuals have given technical advice and contributed their expertise to various aspects of the project:

Aardvark Systems
Eric Arnold
John Chuang
Steve Codell
Lily Lee
Jeff Loeb
Blythe Olshan
Pamela Roth
Philip Sadler
Christopher Unger
Scott Wilder

Special appreciation to David Li, Boston Public School graduate, class of '86, who facilitated the creation of T-Stop Sales.

The Regional Math Network benefitted greatly from the untiring efforts of the Research Assistants and the MidCareer Math and Science Teacher Training Program Fellows. These individuals included:

John Bookston
Lisa Bonanno
John Burnette
Tom Czarny
Mary Eich
Matt Goggins
Randall Hancock
David Masunaga
Joy Moser
Sonya Nelthrop
Matt O'Connor
Eileen O'Sullivan
Joe Patuleia
Joel Poholsky
Jeff Sayah
Scott Smith
Randy Starr
Ted Stein
Jearld Waitkus

A special note of thanks is due to the Production Staff who typed, corrected and retyped the multiple drafts. Their willingness to work toward an improved final copy was impressive.

Steve Codell
Marianne Connolly
Brian Cranton
Scott Cranton
John Domilici
Charles Gerlach
Robert Hafer
Audrey Handelman
Ruskin Hunt
Stuart Klein
Lisa Oray
Robert Sporn
Loralyn Thompson

Particular recognition is given to Michael N. Smith of Laser Designs Corp. of Cambridge for his direction and organization during the final stages of production, and to Randy Hobbs of P&R Publications, who guided the printing process.

Finally, the Regional Math Network gratefully acknowledges the administrators, teachers, students, schools and districts within the region that participated in the development and evaluation of the project materials. The Regional Math Network would not have been possible without their cooperation.

FOREWORD

Mathematics is an increasingly important skill for understanding and appreciating the challenges in our society. Yet the learning of these concepts poses difficulties for many students, especially as they reach the junior high/middle school years. At the same time, mathematics teachers are leaving their profession at a rapid rate, tired of using materials that have not been revised to reflect changes in our society and its workforce. Clearly, a need exists to revitalize both the self-esteem and the teaching resources of those who have chosen this profession. The **Regional Math Network** aims to address these difficulties. The project, **funded by the National Science Foundation**, is sponsored by the Harvard Graduate School of Education.

The overall goal of the Regional Math Network is to invigorate individual teachers and to enhance the quality of the materials and techniques of those in the mathematics teaching profession. To achieve this goal, the Regional Math Network provided 22 Teacher Fellows from eleven school systems with a structured opportunity to collaborate with local business professionals and university personnel in the development of innovative teaching materials and instructional strategies. The school systems represented in the project include Acton, the Archdiocese of Boston, Boston, Cambridge, Chelmsford, Hingham, Lexington, Somerville, Waltham, and the Carroll, the Tower, and the Buckingham, Brown & Nichols Schools.

The **Regional Math Network** also seeks to stimulate math teaching in the greater Boston area. Toward that end, the Network sponsors seminars, receptions and meetings for math teachers and other interested professionals and students. The **Regional Math Network** serves as a model of collaboration on several levels: among different schools in the region, between schools and local businesses, and between these parties and the University, which primarily serves as a facilitator and resource.

A fundamental objective is to produce supplemental materials that are engaging for early adolescents and to improve their interest and ability in problem solving. The Teacher Fellows were organized into four project teams, each with a team leader and graduate research assistants. After conducting a needs and interest assessment within many regional schools and districts, each project team selected a specific context that provided the basis for the consideration of a major mathematical topic traditionally covered in the middle school curriculum. These contexts include an ice cream factory, local sporting events, the solar and space shuttle systems and Quincy Market, a local tourist and commercial area. To better understand the context, teams conferred with members of the local business community and worked with students from Harvard's MidCareer Math & Science Program, former business professionals studying to become mathematics teachers.

Each of these four context areas is linked to specific mathematical topics. While this emphasis does not exclude other related topics, teachers seeking materials on a particular topic may choose to work with a specific unit. The topics of emphasis include:

Ice Cream - Fractions
Math/Space Mission - Estimation, Geometry and Relational Concepts
Quincy Market - Ratio and Proportion
Sports Shorts - Decimals and Percents

All four of the units include a common emphasis on problem posing and problem solving. Many of the activities are open ended, encouraging students to pose their own problems for solving. Other themes and topics common to all of the units stress skills of estimation, graphing, polling, reading and interpreting charts, calculators and computer application and mental arithmetic. All of the materials stress realistic, mathematical applications that are accessible and motivating to middle school students.

Each of the units contains a variety of teacher and student resources. These include teacher notes and teaching suggestions, student pages, answers, activity cards, transparency masters, manipulative materials and classroom games. Additionally, the Quincy Market unit contains a computer disk suitable for any Apple computer.

These materials were written by teachers for other teachers to use. Hence, the materials and format are designed with a teacher's needs and constraints in mind. Comments about these materials are welcomed and may be made by writing to Professor Katherine K. Merseth, The Regional Math Network, Harvard Graduate School of Education, Cambridge, MA 02138.

math space mission

Regional Math Network • Harvard Graduate School of Education • Harvard University

Embark on an Amazing Journey...

OUT OF THIS WORLD!

An Overview for Teachers

MATH / SPACE MISSION

Notes to Teachers

Embark on an amazing journey…out of this world.

This unit is designed to teach estimation skills in such a way as to be relevant and useful to students as they apply them in various problem-solving activities. The teaching activities and the math will be developed within the context of our world and exploration into space and the worlds around us. To incorporate a "local flavor," local people, educational institutions, and businesses are incorporated into lessons where appropriate.

SUMMARY OF ACTIVITIES

MODULE I: **INTRODUCTORY ACTIVITIES**

The introduction to the unit consists of multi-media experiences using videotapes, slides, and films – "grabbers" – to motivate and set the stage for the activities that follow.

MODULE II: **THE SOLAR SYSTEM**

This module explores our planet Earth, its atmosphere, and its relationship to the sun and moon. It then moves out to the other planets and encourages students to become familiar and "travel" within our corner of the galaxy. The activities incorporate direct teaching lessons in rounding numbers; estimation of sums, differences, products, and quotients; graphing; and the application of these skills in problem-solving.

MODULE III: **THE SPACE SHUTTLE**

How will we travel in outer space? In this module, students become familiar with the shuttle, making and using a model of the orbiter, and considering life and work on board. Ratio and proportion as applied to scale models comprise the strong math strand in this module.

MODULE IV: **THE SPACE COLONY**

This module is an interactive experience in which students should stretch their imaginations and apply their skills to build a colony. Where to place the colony in the solar system and how to make it self-sustaining are challenges for the class. Decisions such as how many people would live in it, for how long, and how they will function in it can stimulate group discussions, value clarifications, and decision-making. This module incorporates geometric concepts as students locate the station and build a three-dimensional living space.

Math/Space Mission
Overview
of
Components

Record sheets

During each lesson, students will research and record data which will then be used in estimation activities. Record sheets provide the medium on which the results of student work is written.

Math/Space Mission Fact Book

A FACT BOOK accompanies these modules, giving the teacher the numbers and background needed for all activites and extensions. When activites require students to have specific FACT BOOK information, it will be noted on the record sheet, so that copies can be made. The FACT BOOK also provides students and teachers an opportunity to pose their own questions and do their own data gathering.

Lessons

Teacher notes are provided to accompany each lesson.
They describe:
- materials needed
- preparation required
- math skills developed
- tips on classroom management
- class discussion points

Journal

Each student will maintain a journal during this unit recording his activities and thoughts. Specific journal topics will often be suggested in the lessons.

The Solar System Planet Card Deck

The Planet Card Deck contains useful data about each of the nine planets as well as the sun and moon. They are used in the lessons or can be used as a source of discussion or "problem-making" activites.

Math/Space Mission Problem Deck

The Problem Deck presents problems which relate to and extend the lesson topics. Problem cards are cross-referenced with each lesson and can also be used by students independently.

Math/Space Mission

Overview of Content

MODULE I: **INTRODUCTION**

Page

Embark on an Amazing Journey.......... 11
Space: Here and Now.......... 14
Man's First Space Journey.......... 18

MODULE II: **THE SOLAR SYSTEM**
What's Out There?

Meeting Our Neighbors...Planets Near and Planets Far.......... 28
Meeting Our Neighbors...Planets Large and Planets Small.......... 32
How Far is Pluto?...How Near is Mars?.......... 26
Let's Pretend.......... 44
Let's Extend...Bringing the Planets Down to Earth's Scale.......... 48
Let's Try It...Travelling on Earth.......... 52
Let's Fly It...Travelling in Space.......... 56

MODULE III: **THE SPACE SHUTTLE**
The First Step of the Journey

Leaving Earth ...Its' Atmospheres and Beyond.......... 62
All Aboard.......... 64
The Shuttle ...Let's Make It.......... 76
Creative Blast-Off (Optional).......... 83
Orbiter "Specs".......... 84
"Sure it's Big... But Compared to What?".......... 88
Planning for Life on Board...Let's Eat.......... 92
Planning for Life on Board...Let's Work.......... 98
Planning for Life on Board...Let's Experiment.......... 104
3,2,1 Blast-Off.......... 108
Toys in Space (Optional).......... 114

MODULE IV: **THE SPACE COLONY**
The Threshold for Exploration

From Known to Unknown.......... 130
Where Shall We Locate?.......... 134
Living on the Colony.......... 136
What Will the Colony Be Like?.......... 140
What Next?.......... 146

MATH/SPACE MISSION OVERVIEW OF MATHEMATICAL CONTENT

Activities		Estimation Skills				Measurement								Additional Topics						Activity Coding			
	Page Numbers	Rounding and Comparing Large Numbers	Computation (+, -, x, ÷)	Graphing Data	Scale Models and Scale Drawing	Geometric Figures	Perimeter	Circumference	Area	Surface	Volume	Conversion of Units	Spatial Problem Solving	Ratio and Proportion	Coordinate Graphing	Scientific Notation	Use of Formulae	Logical Problem Solving	Place Value	Discussion/Journal	Core Activity	Reinforcement Activity	Special Challenge
Module I: Introduction																							
Man's First Space Journey	19														●				●				●
We've ComeA Long Way	23			●															●			●	
Name That Planet	25															●						●	
Module II: Solar System																							
How Far Away Are The Planets?	29	●		●																●	●		
How Hot Is It?	31		●																			●	
How Big Are The Planets?	33	●		●																	●		
How Fast?!?	35	●		●																		●	
How Far Is Pluto? How Near Is Mars?	37		●																		●		
Astronomical Units	41	●												●								●	
Learning More About The Solar System	43		●													●						●	
What If The Earth Were 1"?	45	●			●									●							●		
Think of The Earth as a Ball	47				●									●								●	
Sizing Up The Other Planets	49	●			●									●							●		
Create A Model Of The Solar System	51	●			●									●								●	
Let's Take A Trip	53		●					●				●					●				●		
More Trips	55		●					●				●					●					●	
Let's Send Jesse	57		●																		●		●
Let's Fly It	59		●									●										●	●
Module III: The Space Shuttle																							
Leaving Earth	63			●	●																●		
Mission Control	65														●							●	
All Aboard	67																			●			

MATH/SPACE MISSION OVERVIEW OF MATHEMATICAL CONTENT

		Estimation Skills				Measurement								Additional Topics						Activity Coding			
Activities	Page Numbers	Rounding and Comparing Large Numbers	Computation (+, -, x, ÷)	Graphing Data	Scale Models and Scale Drawing	Geometric Figures	Perimeter	Circumference	Area	Surface	Volume	Conversion of Units	Spatial Problem Solving	Ratio and Proportion	Coordinate Graphing	Scientific Notation	Use of Formulae	Logical Problem Solving	Place Value	Discussion/Journal	Core Activity	Reinforcement Activity	Special Challenge
All Aboard Coordinate Puzzle	75														●							●	
Orbiter Blueprints	77				●	●															●		
The Shuttle	79		●		●																	●	
Creative Blast-off	83																	●		●		●	
Orbiter Specs	85				●									●							●		
The Shuttle System	87				●				●													●	
More Comparisons	89	●	●											●							●		
Sure It's Big...	91		●											●								●	
Let's Eat	93		●															●			●		
Crew's Quarters	97		●		●				●														●
Let's Work	99					●			●	●	●											●	
Finishing The Job	101				●	●			●	●	●		●										●
Let's Experiment	105		●		●	●				●	●										●		
Get Away Specials	107		●		●	●				●	●		●									●	
3,2,1 Blastoff	109		●									●		●			●					●	
Completing The Ride	111		●									●					●						●
Gemini Capsule	113				●				●													●	
Toys in Space	115																			●			●
Module IV: The Space Colony																							
The Colony Connection	131		●	●																		●	
Where Shall We Locate?	135				●								●							●	●		
Solar Cells: Power From The Sun	137		●						●												●		
Solar Cells: Source Of Energy	139		●						●													●	
My Space Colony	141				●	●				●	●		●	●							●		●
A Cubic Colony	143				●	●							●							●		●	●
More Cubic Colonies	145				●	●							●									●	
What Next?	146																			●			

space

here and now

ACTIVITIES

MODULE I: **INTRODUCTION**
Space: Here and Now

- Embark on An Amazing Journey
- Space Here and Now
- Man's First Space Journey

Embark on an Amazing Journey...

OUT OF THIS WORLD!

Tin Can Space Suit - Designed in the 1960's

EMBARK ON AN AMAZING JOURNEY

A "Media" Introduction to Space and Space Exploration

Guidelines for Teachers

To capture and excite the students about space, engage them in a "media" experience by:

- Viewing slides such as:
    - -- those available from the Jet Propulsion Laboratory at modest cost.
- Viewing a television show such as:
    - -- "Great Space Race" (PBS)
    - -- "Cosmos Series" (PBS)
- Taking a field trip such as:
    - -- Museum of Science, Science Park, Boston, MA 723-2500
      Special programs in science and space can be arranged.
      Contact person is Matt Stein.
    - -- Smithsonian Astrophysical Observatory, Pinnacle Road, Harvard, MA 456-3395
      This is a privately funded group engaged in "listening" activities for research on outer space.
      Contact person is Skip Schwartz.
    - -- Hayden Planetarium, Museum of Science, Science Park, Boston, MA 723-2500
      Planetary show can be planned for school groups;
      free shows on Friday evenings.

To focus the students' interests on space, you might consider these pointers:

- The more you enliven the room with posters and pictures, the more provocative the environment will be to stimulate good and varied questions

- The teacher and student should not be intimidated by their lack of knowledge or number of questions concerning the solar system and the shuttle program. The "media" should be presented in an informal manner, with reactions in the form of both comments and questions.

- You may plan as much or as little time in the media activities as you wish. They serve to set the stage for questions and interest.

- Many discussion topics for the slides and films are suggested. You may use them as you wish. You should pick the ones with which you feel most comfortable.

- You may prefer to start each class with one question.

- Many questions have no right or wrong answers. They are valuable however, because they provoke the students' curiosity and encourage them to use their imaginations.

- For those questions whose answers are not immediate, the students may research the issue raised.

To extend the unit to include a broader scope:

- Journal:

  Students could be encouraged to keep a journal reflecting on their activities "in space." Specific topics for the journal will be suggested when appropriate.

- Other subject areas:

  The context of space is rich with opportunities to develop topics in other subject areas. Many of the activities deal with science topics, which can be emphasized and highlighted to complement goals of the science curriculum. The journal encourages a Language Arts involvement. The discussions can be extended to goverment, philosophy, or ethics. Throughout the unit, music, art, and poetry may be introduced to express thoughts and conjectures.

- Students might form a "Space Club" for independent study, research, and activities.

SPACE: HERE AND NOW

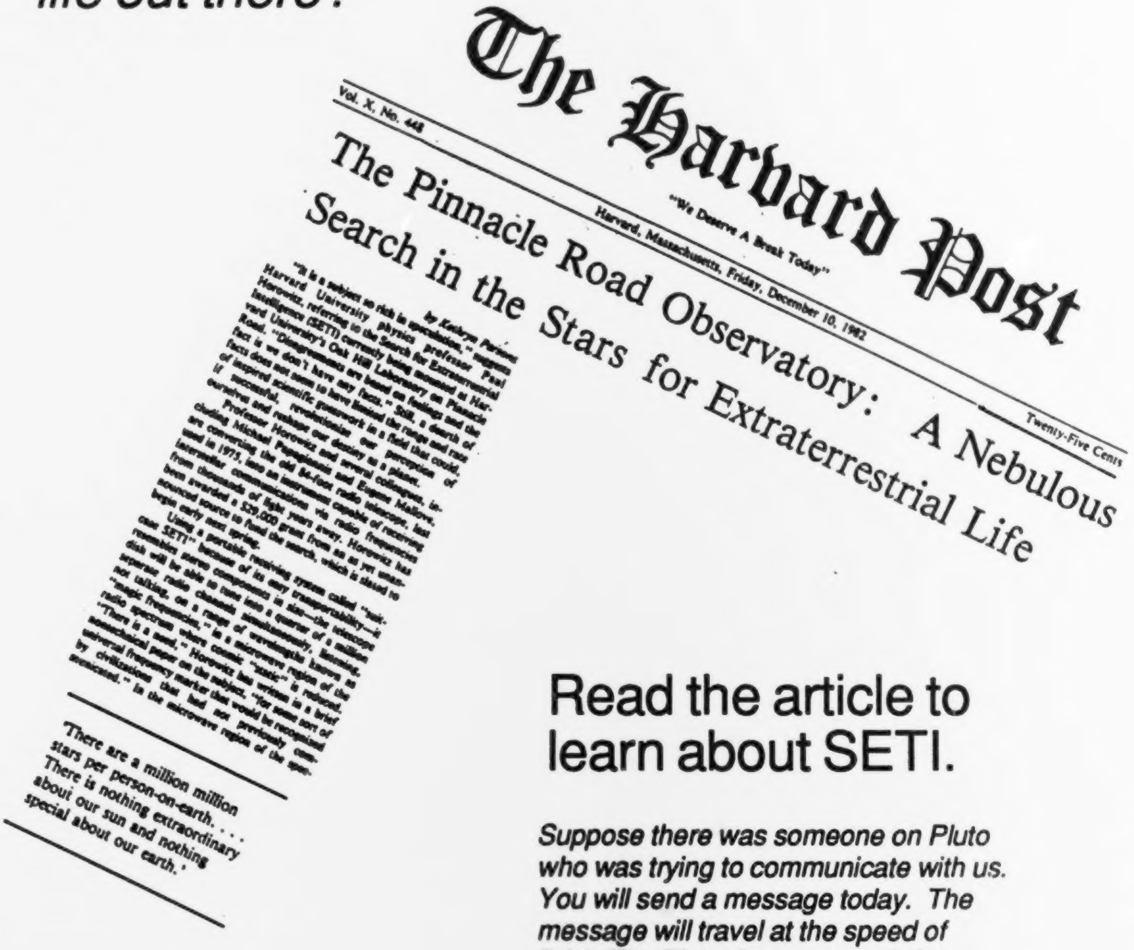
Preparation/Materials	**Math Skills**
• Review Fact Book-Solar System Data • "Connect the Coordinates"	• Prediction and Problem Solving

During class:

- Invite the students to launch a space exploration mission.
- Explain that we must make all the necessary preparations, including reviewing what we know about the solar system, readying a transportation plan, and finally building a space station at the outer reaches of our solar system so we can extend our explorations.
- To add motivation, the space exploration could be directed to the goal of searching for intelligent life. Both the U.S. and the U.S.S.R. have goverment-sponsored projects which are seeking signs of intelligent life elsewhere in the Universe. In the U.S. it is called the SETI project, or the Search For Extraterrestrial Intelligence. The primary tools are large radiotelescopes which listen for signals from intelligent civilizations. Students can read about them in the article included in the Fact Book.
- Describe the three parts of the unit and of our space exploration:
  - The Solar System: What's Out There?
  - The Shuttle System: The First Step of the Journey
  - The Space Colony: The Threshold for Exploration
- Discuss any questions the students may have about space and the problems they think we may encounter in these exploration activities.

Extensions
- Read and discuss "The Pinnacle Road Observatory..."
- Journal Entry: "What Do You Wonder About Space?"

Is there intelligent life out there?



The Harvard Post

"We Deserve A Break Today"

Vol. X, No. 448 Harvard, Massachusetts, Friday, December 10, 1982 Twenty-Five Cents

The Pinnacle Road Observatory: A Nebulous Search in the Stars for Extraterrestrial Life

"There are a million million stars per person-on-earth. . . . There is nothing extraordinary about our sun and nothing special about our earth."

Read the article to learn about SETI.

Suppose there was someone on Pluto who was trying to communicate with us. You will send a message today. The message will travel at the speed of light. The Plutonian answers it the moment the message is received.

How long will it take before the reply arrives?

What else do you wonder about?

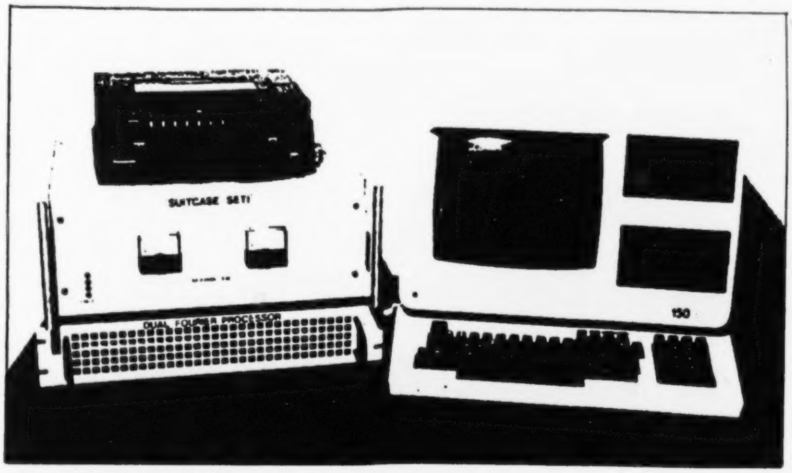
The Harvard Post

"We Deserve A Break Today"

Vol. X, No. 448 Harvard, Massachusetts, Friday, December 10, 1982 Twenty-Five Cents

The Pinnacle Road Observatory: A Nebulous Search in the Stars for Extraterrestrial Life

by Kathryn Parsons



The 'suitcase SETI' will take the message when other civilizations call.

"It is a subject so rich in speculation," suggests Harvard University physics professor Paul Horowitz, referring to the Search for Extraterrestrial Intelligence (SETI) currently being mounted at Harvard University's Oak Hill Laboratory on Pinnacle Road. "Disagreements are based on feelings and the fact is we don't have any facts." Still, a dearth of facts does not seem to have limited the range and rate of inspired scientific guesswork in a field that could, if successful, revolutionize our perception of ourselves and reshape our destiny as a planet.

Professor Horowitz and several colleagues, including Michael Papagiannis and Eugene Mallove, are converting the old 84-foot radio telescope, last used in 1975, into an instrument capable of receiving interstellar communications via radio frequencies from thousands of light years away. Horowitz has been awarded a $29,000 grant from an as yet unannounced source to fund the search, which is slated to begin early next spring.

Using a portable receiving system called "suitcase SETI" because of its easy transportability—it resembles stereo components in size—the telescope dish will be able to tune into a quarter of a million separate radio channels simultaneously, listening, not talking, on a range of wavelengths known as "magic frequencies," in a microwave region of the radio spectrum where cosmic "static" is reduced. "There is a need," Horowitz has written in a brief nontechnical paper on the subject, "for some sort of universal frequency marker that would be recognized by civilizations that had not previously communicated." In the microwave region of the spectrum there is a "magic frequency" emitted naturally by neutral hydrogen atoms. Horowitz explains these are "the simplest and most abundant atoms in the universe; [their] radiation must be well known by astronomers everywhere." "Everywhere" includes every potential source of extraterrestrial signal in two-thirds of the sky, or one million "candidate stars."

> 'There are a million million stars per person-on-earth. . . . There is nothing extraordinary about our sun and nothing special about our earth.'

Extremely precise in its ability to delineate frequencies, receiving apparatus has evolved since the 1960 Ozma Project, the first galactic search, to become smaller, cheaper, and more powerful, able to pick up signals and deliver them to an observer almost instantaneously. Putting SETI and its equipment in an historical perspective, Horowitz quotes Massachusetts Institute of Technology (MIT) professor Philip Morrison: " 'The Nina, the Pinta, and the Santa Maria weren't jet planes, but they did the job.' The total system we're talking about," Horowitz continues, "amounts to a mosquito flapping its wings a few times. It's an extremely sensitive science."

"We know the facts. We know they're out there," Horowitz says cheerfully as he fiddles with the heating dials on a recent dank November day in an office whose walls and floor are covered with scientific journals. Horowitz, who reserves his Sundays for Harvard, appears at the doorway of the small cinder block structure behind the radio telescope at Oak Hill Observatory wearing a green ski cap and work clothes, eager to get on with a job that may put the planet on the threshhold of a realm of possiblities.

"There's a lot of support," he says, smiling, "from stodgy old professors sort of over the bend, like me." (Horowitz is in his mid-thirties.) "There's a lot of curiosity to do the experiment, to rule out the probability that the sky is alive with signals."

Belief in the existence of other technological civilizations seems widespread and is based on the observation that nature does not go in for a single phenomena. "We don't see unique examples of things in nature," Horowitz points out, suggesting that the sheer numbers—three billion stars in our galaxy that might have appropriate planets orbiting them, and ten billion galaxies—rule out the possibility that ours is the only planet in the universe sustaining an advanced civilization. "There are a million million stars per person on earth, so there would seem to be a lot of chances. . . . There is nothing extraordinary about our sun and nothing special about our earth. Carl Sagan is a bit of an optimist on these matters. A pessimist," Horowitz remarks, "would probably say there is only one technological civilization in the galaxy, but I don't like statistical arguments where you have to be a statistical anomaly."

While it would be possible, though extremely expensive, to communicate by gamma rays or rocket ship (to go to the nearest star would cost the equivalent of a half million years of United States power consumption), or to hurl projectiles into the universe like carrier pigeons, sending radio frequencies appears to be a "more hopeful and cheaper" route. In the last twenty years there have been 33 such searches conducted in seven countries involving twelve different radio observatories around the world, says Papagiannis, who is an astronomy professor at Boston University and president of the International Astronomical Union, and is himself an enthusiast in the search for extraterrestrial intelligence.

"When the first detection comes it will be like a beacon—a kind of signal intended to attract attention," Horowitz suggests. Looking for a signal is primarily a matter of listening. Once communication is established, scientists will use a synthetic language called Cosma Lingua that starts with science and math as a means to establish a common understanding of symbols and from there progresses into more philosophical and abstract territory. "It is as if you went back to Chaucer's time and showed them a computer. Most of the communication is going to be one way at first, a pair of monologues running back and forth. . . ."

It is obvious to most scientists that the impact of an interstellar dialogue would be tremendous, revolutionizing our view of ourselves and our universe. Still, although there are any number of divergent opinions about whether there are other technological civilizations and where they may be, differences are dwindling in the face of the overwhelming thrust toward "a coordinated, worldwide, and systematic search for extraterrestrial intelligence," which Carl Sagan urged in an international petition in Science magazine last month.

There are those who speculate that the galaxy is populated by a wise and watchful multitude. "They might be all over the place," says Mallove, president of Astronomy New England and a volunteer in the SETI project. "The colonies might leapfrog from star to star in a cosmic lifetime to quickly populate the entire galaxy." Since 1977, the company Mallove started with a friend has functioned as a mail order business, developing products that attractively illustrate principles of astronomy. As he breezed into the office he set down a delicate three-dimensional "map" of the solar system showing the relationship of the stars that are nearest the sun up to a distance of 21 light years away. Each star is a ball the size of the head of a pin, painted in neon colors keyed to show distinct and shared properties.

After graduating from MIT in the Aero-Astro Department of Engineering, Mallove, a resident of Holliston, worked on advance propulsion concepts. But now, "sick of doing death and destruction work," he is hoping to sell a syndicated series of articles, called "Star Bound," on space travel, astronomy, and SETI. Although he is enthusiastic about the Harvard SETI project, Mallove himself is interested in the concept of interstellar travel in space arks, or "generation ships"—closed life systems transporting to the stars the ancestors of those who will eventually arrive. "I come from that side of the SETI argument," he says.

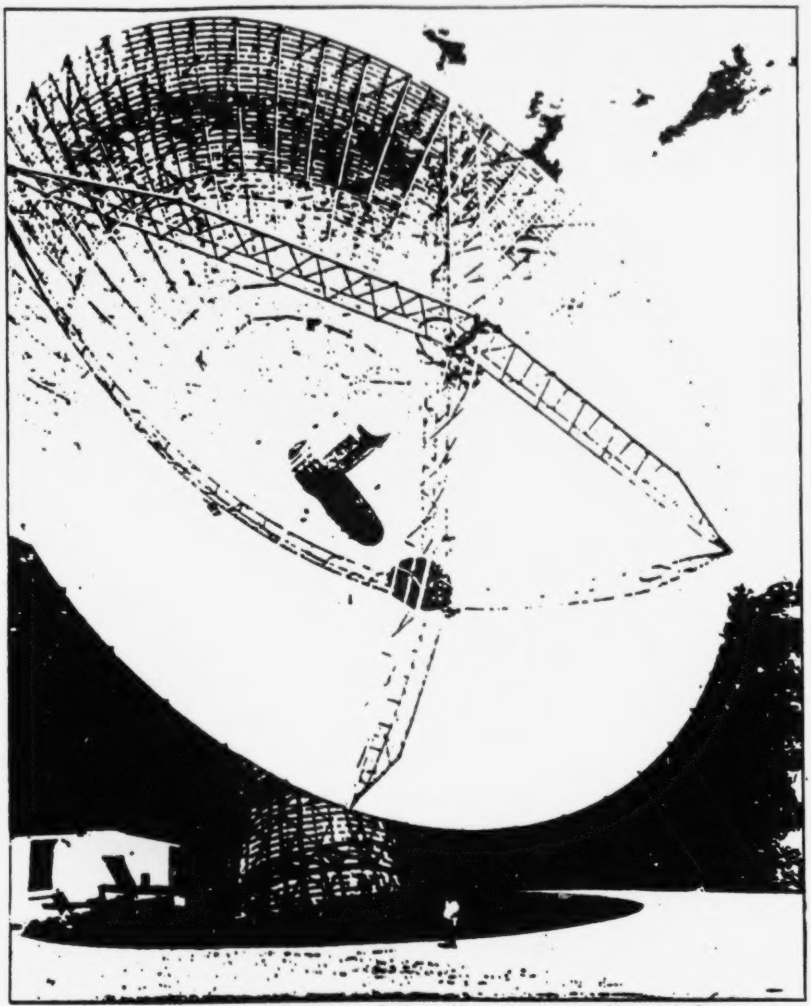
According to Papagiannis, there are two possible "scenarios." "It is a matter of preference," he says. "Whichever one you adopt depends on how you see things." In the first scenario, a civilization starts in a star system and stays in that star system always. "If you follow that scenario," he adds, "you only look at the distant stars for possible sources of life." In the second, a technological civilization does not stay put, but moves in successive waves to colonize neighboring stars. If you are a second-scenario advocate, like Papagiannis and Mallove, you must also adopt the notion that it would be well to look within our own solar system for colonies much closer to home. If no signals are forthcoming, it can be assumed, suggests Papagiannis, that "the colonization wave has not swept through the galaxy [and] that extraterrestrial life has not developed to a level of technology similar to or more advanced than our own."

"I, too, wonder why they're not all over the place. If they're not they must be very, very rare," says Mallove. Despite his own pet theories, Mallove is excited about the effect of any kind of interstellar communication that, once established, could advance our civilization immeasurably toward new survival strategies. "We will have to act as a planet instead of several disparate entities," he comments.

Papagiannis believes that "if the galaxy has already been colonized, galactic civilizations would have established their space colonies in the asteroid belt—an ideal source of raw materials for space habitats. It would be inexcusable, he says, "to keep searching for signs of galactic civilizations in faraway stars when the evidence could possibly be found in our immediate vicinity."

At its general assembly last August in Paros, Greece, the International Astronomical Union established a new commission, Search for Extraterrestrial Life, and elected Papagiannis as the first president. The commission, which already has 200 members, will coordinate research activities on the search for extraterrestrial life at the international level. Activities include the search for planets in other solar systems; the search for radio signals, intentional or unintentional, from other galactic civilizations; the study of biologically important interstellar molecules; and spectroscopic studies of biological activities in other solar systems. "The endorsement of this young field by the international society of the International Astronomical Union . . . a significant step in the efforts of scientists to mount a concerted project to search for life in the universe," Papagiannis adds.

If the Oak Hill SETI project in Harvard receives a galactic signal, it will be the first. Paul Horowitz is really looking forward to it.



The radio telescope at the Harvard Observatory. Professor Horowitz's six-year-old son is in foreground.
(Photos courtesy of Paul Horowitz)

MAN'S FIRST SPACE JOURNEY

Preparation/Materials	Math Skills
"Man's First Space Journey"	Coordinate Graphing Place Value of Large Numbers Factors and Primes

During class:

- After an introduction to space travel and the solar system, ask students to plot and connect the points on the coordinate graph, "Man's First Space Journey."
- Use either of the two problem sheets to name the coordinate points.
  - For a simpler version, use the problem sheet on which the coordinates of the points are clearly given and the students simply locate the points.
  - For a challenging activity, use the problem sheet on which problems must be solved in order to determine the numerical values of the coordinates.

Extensions
- "We've Come a Long Way (Time Line)"
- "Name the Planet"

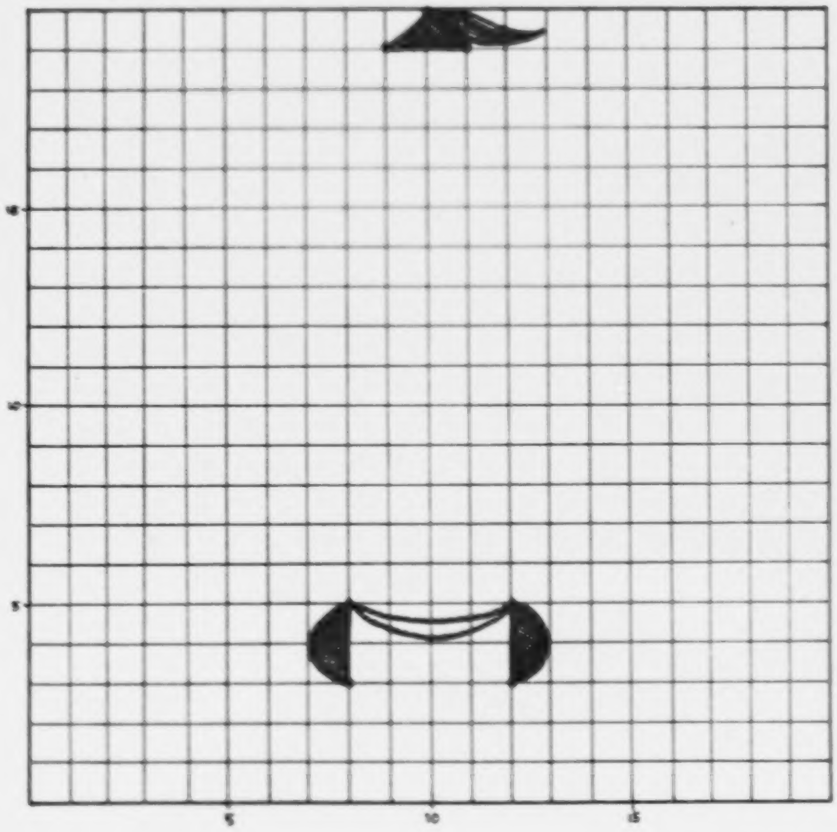
Name ____________________

CONNECT THE COORDINATES
MAN'S FIRST SPACE JOURNEY

Label and plot these points on the graph and connect them.

A: (x,y) = (9, 19)
x coordinate = 9
y coordinate = 19
B: (6,17)
C: (4,14)
D: (4,9)
E: (8,7)
F: (8,5)
G: (8,3)

H: (10,3)
I: (12,3)
J: (12,5)
K: (12,7)
L: (15,9)
M: (16,12)
N: (16,14)
O: (14,17)
P: (11,19)



CONNECT THE COORDINATES MAN'S FIRST SPACE JOURNEY

An ordered pair is usually written (x,y), where x is the coordinate on the x-axis and y is the coordinate on the y-axis. (x,y)

Find the Coordinates of A-P.

POINT COORDINATES OF POINT

A 1937
______x coordinate = digit in hundreds place
______y coordinate = total number of hundreds in the number

B The nearest star is Proxima Centauri.
It is one hundred seventeen million miles away from earth.
______x coordinate = number of zeroes in the number
______y coordinate = number of millions in number when one hundred million is subtracted from it.

C "four million one hundred and seven thousand and fourteen"
______x coordinate = number of millions
______y coordinate = two times the number in the thousands place

D Scientists think the sun has existed for nearly five trillion years.
______x coordinate = number of inner planets
______y coordinate = three less than the number of zeroes in the number of years the sun has existed

E Experts say our earth is 4,500,000,000 years old.
______x coordinate = number of zeros in the number
______y coordinate = the common factor of 14 and 19

F Some experts say our galaxy has about four hundred million stars.
______x coordinate = number of zeroes in the number
______y coordinate = the common factor of 15 and 25

G Humans have existed on earth about five hundred thousand years.
______x coordinate = number of planets in our solar system other than the earth
______y coordinate = two less than the number of zeroes in the number of years humans have existed.

POINT COORDINATES OF POINT

H Scientists estimate that approximately 6,400,000,000,000 people have existed since the earth has existed.
______x coordinate = sum of the first two digits in the number
______y coordinate = the common factor of 12 and 45

I 12,357
______x coordinate = number of thousands in the number
______y coordinate = digit in the hundreds place

J ______x coordinate = half the number of hours in a day on Mars
______y coordinate = number of moons of Uranus

K The distance of the nearest sun to our sun is 40,070,000,000,000,000,000.
______x coordinate = number of zeroes after the trillions
______y coordinate = number of zeroes in sixty million

L ______x coordinate = number of zeroes in 7 quadrillion
______y coordinate = number of hours in a day on Jupiter

M 16,231,276
______x coordinate = number of millions in this number
______y coordinate = digits in the thousands and hundreds place

N ______x coordinate = number of moons orbiting Jupiter
______y coordinate = least common multiple of 2 and 7

O ______x coordinate = two less than the number of Jupiter's moons
______y coordinate = sum of Jupiter's moons and Earth's moon

P ______x coordinate = the fifth prime number
______y coordinate = ten more than the number of planets in our solar system

Regional Math Network • Harvard Graduate School of Education • Harvard University

Mankind's journey into space began in 1783 when people boarded primitive hot-air balloons and floated away from the Earth's surface.

Poster

CONNECT THE COORDINATES MAN'S FIRST SPACE JOURNEY

An ordered pair is usually written (x,y), where x is the coordinate on the x-axis and y is the coordinate on the y-axis. (x,y)

Find the Coordinates of A-P.

POINT COORDINATES OF POINT

A 1937
9 x coordinate = digit in hundreds place
19 y coordinate = number of hundreds in the number

B The nearest star is Proxima Centauri.
It is one hundred seventeen million miles away from earth.
6 x coordinate = number of zeroes in the number
17 y coordinate = number of zeroes in number when one hundred million is subtracted from it.

C "four million one hundred and seven thousand and fourteen"
4 x coordinate = number of millions
14 y coordinate = number of zeroes in the number

D Scientists think the sun has existed for nearly five trillion years.
4 x coordinate = number of inner planets
9 y coordinate = number of zeroes in the number of years the sun has existed

E Experts say our earth is 4,500,000,000 years old.
8 x coordinate = number of trillions in the number
7 y coordinate = number of billions in the number

F Some experts say our galaxy has about four hundred million stars.
8 x coordinate = number of zeroes in the number
5 y coordinate = the common factor of 14 and 49

G Humans have existed on earth about five hundred thousand years.
8 x coordinate = number of planets in our solar system other than the earth
3 y coordinate = number of zeroes in the number of years humans have existed.

POINT COORDINATES OF POINT

H Scientists estimate that approximately 6,400,000,000,000 people have existed since the earth has existed.
10 x coordinate = number of zeroes that follow the billions place
3 y coordinate = the common factor of 12 and 45

I 12,357
12 x coordinate = number of thousands in the number
3 y coordinate = digit in the hundreds place

J 12 x coordinate = number of radio observatories in the world searching for "messages" (see article)
5 y coordinate = number of moons of Uranus

K The distance of the nearest sun to our sun is 40,070,000,000,000,000,000.
12 x coordinate = number of zeroes after the quadrillions
7 y coordinate = number of zeroes in sixty million

L 15 x coordinate = number of zeroes in 7 quadrillion
9 y coordinate = number of satellites orbiting Saturn

M 1,623,151,276
16 x coordinate = number of hundreds of millions in this number
12 y coordinate = digits in the thousands and hundreds place

N 16 x coordinate = number of moons orbiting Jupiter
14 y coordinate = least common multiple of 2 and 7

O 14 x coordinate = sum of Uranus' moons and rings
17 y coordinate = sum of Jupiter's moons and rings

P 11 x coordinate = the fifth prime number
19 y coordinate = number of planets in our solar system

Regional Math Network • Harvard Graduate School of Education • Harvard University

WE'VE COME A LONG WAY...

Here is a list of "firsts" in space thoughout history. Record each date. List the dates in chronological order. Graph the events on a time line.

Date

A. The first air stewardess was Ellen Church, who made her flight on May 15, 1930, on United Air Lines. A.________

B. The Wright brothers ushered into the world their epoch making invention of the first successful aeroplane flying machine at Kill Devil Hills, south of Kitty Hawk, N.C. December 17, 1903. B.________

C. The XP-59, the first jet-propelled airplane designed and built in the U.S. was flown on Oct. 1, 1942, at a secret testing base in Muroc, Calif. The jet's speed was 400 m.p.h. It flew at a height in excess of 40,000 feet. C.________

D. The first dirigible flight was schedule for July 3, 1878, with John Wise, of Lancaster, Pa. as the pilot. The dirigible was shaped like a cigar and had a wicker cage, partitioned with a door and window. D.________

E. Blanche Stuart Scott made a solo flight on October 23, 1910, in Fort Wayne, Ind., becoming the first women aviator to make a public flight. E.________

F. The first airplane flight was made Aug. 14, 1901, near Bridgeport, Conn., by Gustave Whitehead, in his airplane "No. 21." F.________

G. First transatlantic solo flight from New York to Paris was made by Charles Lindbergh on May 20, 1927. G.________

Date

H. The first balloon flight was made by Edward Warren, 13 years old, on June 23, 1784, at Baltimore, Maryland. H.________

I. The first glider flight occured on a hillock, south of the valley of Otay, Calif., on March 17, 1884, by John Joseph Montgomery. The glider traveled about 600 feet. I.________

J. The first launching of a liquid-fueled rocket was made by Dr. Robert Goddard at Auburn, Mass., on March 16, 1926. J.________

K. The first artificial satellite, named "Sputnik" ("Fellow Traveler") was put into orbit on Oct. 4, 1957, from the USSR. It reached a velocity of more than 17,750 mph. K.________

L. The first successful manned space flight began in USSR on April 12, 1961. L.________

M. The first woman to orbit the earth was Valentina Vladimirovna Tereshkova, who was lauched in Vostok VI from Tyura Tam, USSR, at 9:30 am on June 16, 1963. She returned on June 19,1963, after completing over 48 orbits (1,225,000 miles). M.________

N. The Voyager aircraft was the first to circumnavigate the globe without refueling. It completed its flight in December, 1986. N.________

WE'VE COME A LONG WAY...

Here is a list of "firsts" in space thoughout history. Record each date. List the dates in chronological order. Graph the events on a time line.

Date (rank)

A. The first air stewardess was Ellen Church, who made her flight on May 15, 1930, on United Air Lines.

A. 1930 (9)

B. The Wright brothers ushered into the world their epoch making invention of the first successful aeroplane flying machine at Kill Devil Hills, south of Kitty Hawk, N.C. December 17, 1903.

B. 1903 (5)

C. The XP-59, the first jet-propelled airplane designed and built in the U.S. was flown on Oct. 1, 1942, at a secret testing base in Muroc, Calif. The jet's speed was 400 m.p.h. It flew at a height in excess of 40,000 feet.

C. 1942 (10)

D. The first dirigible flight was schedule for July 3, 1878, with John Wise, of Lancaster, Pa. as the pilot. The dirigible was shaped like a cigar and had a wicker cage, partitioned with a door and window.

D. 1878 (2)

E. Blanche Stuart Scott made a solo flight on October 23, 1910, in Fort Wayne, Ind., becoming the first women aviator to make a public flight.

E. 1910 (6)

F. The first airplane flight was made Aug. 14, 1901, near Bridgeport, Conn., by Gustave Whitehead, in his airplane "No. 21."

F. 1901 (4)

G. First transatlantic solo flight from New York to Paris was made by Charles Lindbergh on May 20, 1927.

G. 1927 (8)

Date (rank)

H. The first balloon flight was made by Edward Warren, 13 years old, on June 23, 1784, at Baltimore, Maryland.

H. 1784 (1)

I. The first glider flight occured on a hillock, south of the valley of Otay, Calif., on March 17, 1884, by John Joseph Montgomery. The glider traveled about 600 feet.

I. 1884 (3)

J. The first launching of a liquid-fueled rocket was made by Dr. Robert Goddard at Auburn, Mass., on March 16, 1926.

J. 1926 (7)

K. The first artificial satellite, named "Sputnik" ("Fellow Traveler") was put into orbit on Oct. 4, 1957, from the USSR. It reached a velocity of more than 17,750 mph.

K. 1957 (11)

L. The first successful manned space flight began in USSR on April 12, 1961.

L. 1961 (12)

M. The first woman to orbit the earth was Valentina Vladimirovna Tereshkova, who was lauched in Vostok VI from Tyura Tam, USSR, at 9:30 am on June 16, 1963. She returned on June 19,1963, after completing over 48 orbits (1,225,000 miles).

M. 1963 (13)

N. The Voyager aircraft was the first to circumnavigate the globe without refueling. It completed its flight in December, 1986.

N. 1986 (14)

Name ______________________

Name that planet!!

?

USE YOUR RULER TO MATCH EXPRESSIONS ON THE LEFT WITH THE SAME VALUE ON THE RIGHT.

THE LETTERS WHICH DO NOT HAVE A LINE THROUGH THEM CAN BE USED TO SPELL OUT THE NAME OF ONE OF THE PLANETS

1.7×10^{9}

6.48×10^{5}

1.193×10^{-1}

6.48×10^{3}

9.936×10^{-3}

7.43×10^{2}

6.39×10^{-3}

Ⓟ Ⓘ Ⓜ Ⓒ Ⓗ Ⓙ Ⓝ Ⓔ Ⓤ Ⓣ Ⓞ Ⓡ

.1193

6480

648000

.00936

1700000000

.00639

743

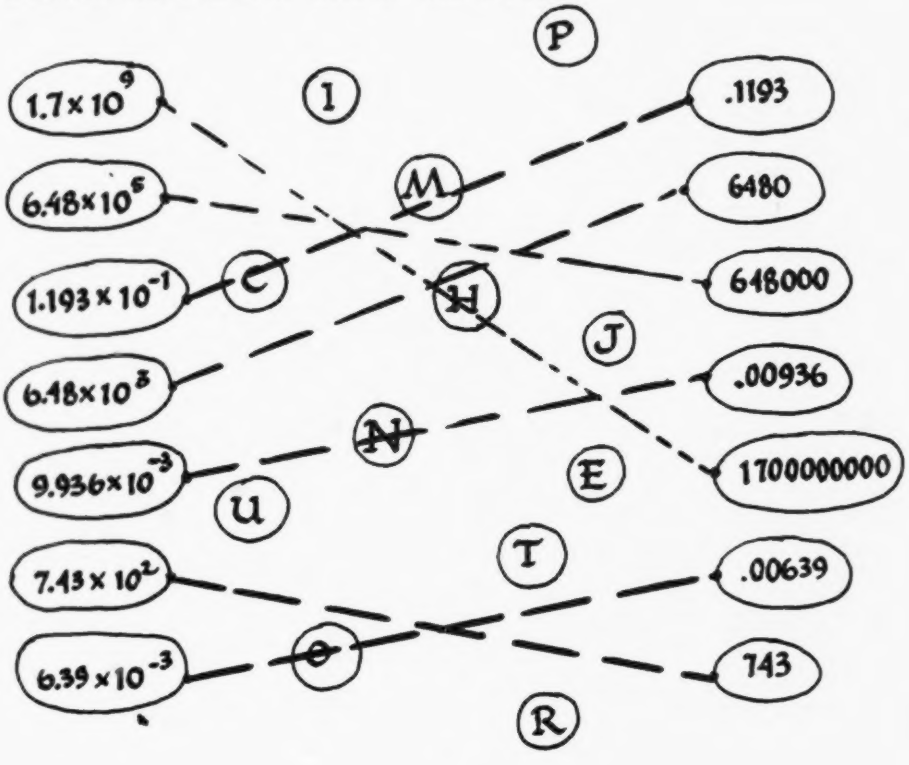
It will take approximately 22,000 hours to get to this planet, traveling at 17,500 miles per hour. Calculate the approximate distance of this planet from the sun.

Name ____________________________

Name that planet!!

USE YOUR RULER TO MATCH EXPRESSIONS ON THE LEFT WITH THE SAME VALUE ON THE RIGHT.

THE LETTERS WHICH DO NOT HAVE A LINE THROUGH THEM CAN BE USED TO SPELL OUT THE NAME OF ONE OF THE PLANETS

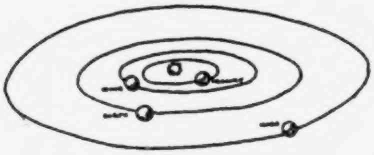


It will take approximately 22,000 hours to get to this planet, traveling at 17,500 miles per hour. Calculate the approximate distance of this planet from the sun.

ACTIVITIES

MODULE II: **THE SOLAR SYSTEM**
What's Out There?

Meeting Our Neighbors...Planets Near and Planets Far
Meeting Our Neighbors...Planets Large and Planets Small
How Far is Pluto?...How Near is Mars?
Let's Pretend...
Let's Extend...Bringing the Planets Down to Earth's Scale
Let's Try It...Travelling on Earth
Let's Fly It...Travelling in Space



MEETING OUR NEIGHBORS... PLANETS NEAR AND PLANETS FAR

Preparation/Materials	Math Skills
• Review "All You Need to Know About the Solar System" in the Fact Book • Review "Rounding" in the Fact Book • "How Far Away Are The Planets?" • "Summary of Facts", Fact Book • Graph Paper • Planet Cards (Optional)	• Rounding and Comparing Large Numbers • Graphing Data

During Class:

- Brainstorm with the students about the number of planets, their names, and their distances from the sun. Distributing the Planet Cards to students may invite interesting discussion.
- Discuss why you round and how to choose an appropriate rounding place.
- Look up, record, and round* the distances of the planets from the sun, using "Summary of Facts" in the Fact Book.
- Advise students to save the "Summary of Facts" for work in later lessons.
- After rounding the distances, order the planets and record them in terms of their distances from the sun.
- Draw a bar graph of the rounded distances of the planets from the sun.
- Discuss:
    - Which planet is the farthest from the sun?...the closest to the sun?
    - Which are the so called outer planets? (Jupiter, Saturn, Uranus, Neptune, and Pluto)...the inner planets? (Mercury, Venus, Earth, Mars)
    - There is speculation that there may have once been a tenth planet. Where might it have been?...Why?
    - Is there any air in space?**
    - Is it hot in space?..Is it cold?**

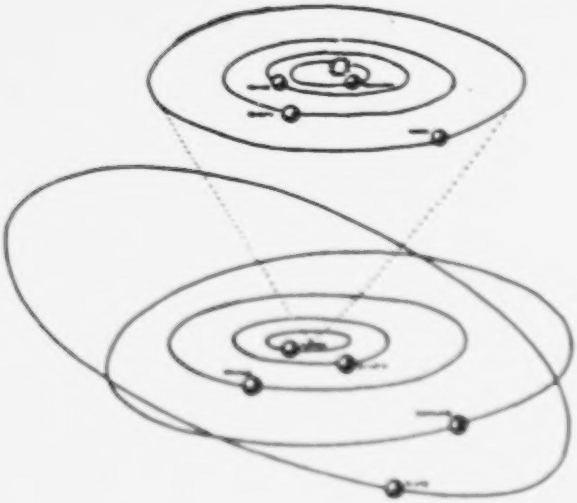
Extensions

- "How Hot is it?"
- Create a mnemonic to represent the order of the planets:
  My Very Educated Mother Just Served Us Nine Pizzas
- Exponential and Scientific Notation

* Indicates that there are specific Teaching Approaches in the Math Facts section of the Fact Book.

** These questions and other interesting points are discussed in the Solar System Data Section of the Fact Book.

Name ____________________

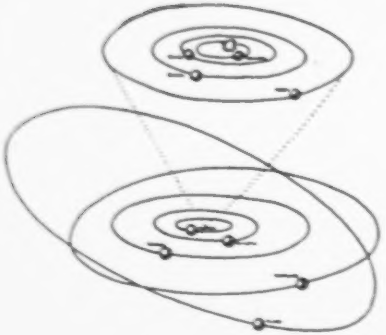


HOW FAR AWAY ARE THE PLANETS FROM THE SUN?

(Use the table of Approximate Distances Between Planets in Fact Book)

Planets in Order	The Distance of the Planets from the Sun (in miles)	Rounded Distance from the Sun (in millions of miles)

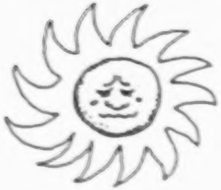
Name ____________________



HOW FAR AWAY ARE THE PLANETS FROM THE SUN?

(Use the table of Approximate Distances Between Planets)

Planets in Order	The Distance of the Planets from the Sun (in miles)	Rounded Distance from the Sun (in millions of miles)
Mercury	35,980,103	36,000,000
Venus	67,240,115	67,000,000
Earth	92,963,115	93,000,000
Mars	141,642,351	142,000,000
Jupiter	483,625,103	484,000,000
Saturn	890,613,004	891,000,000
Uranus	1,782,020,003	1,782,000,000
Neptune	2,794,444,010	2,794,000,000
Pluto	3,654,410,091	3,654,000,000

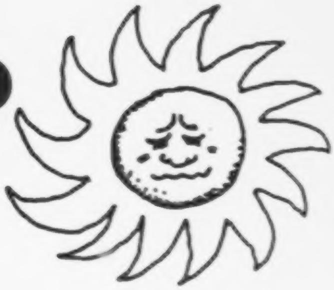


Name ____________________

HOW HOT IS IT?

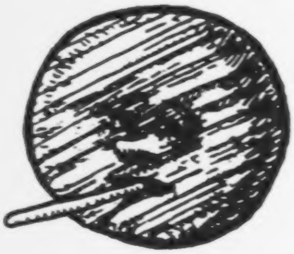
	MAXIMUM TEMPERATURE	MINIMUM TEMPERATURE
Mercury	660°	-270°
Venus	896°	-27°
Earth	136.4°	-126.9°
Mars	80°	-190°
Jupiter	53,500°	-140°
Saturn	*	-292°
Uranus	*	-346°
Neptune	*	-364°
Pluto	-382°	-390°

1. Which are the three warmest planets? Jupiter, Mercury, Venus
2. Which is the coldest planet? Pluto
3. Are the planets that are closest to the sun the hottest? No, Jupiter
4. Which planet has the greatest range of temperature? Jupiter
5. What is the range of temperature on Earth? -126.9 to 136.9 = 263.3 change
6. On which planets do the highest and lowest temperatures vary about 300°?
   Mars and Earth



Name ______________________

HOW HOT IS IT?



	MAXIMUM TEMPERATURE	MINIMUM TEMPERATURE
Mercury		
Venus		
Earth		
Mars		
Jupiter		
Saturn		
Uranus		
Neptune		
Pluto		

1. Which are the three warmest planets?
2. Which is the coldest planet?
3. Are the planets that are closest to the sun the hottest?
4. Which planet has the greatest range of temperature?
5. What is the range of temperature on Earth?
6. On which planets do the highest and lowest temperatures vary about 300°?

MEETING OUR NEIGHBORS...
PLANETS LARGE AND PLANETS SMALL

Preparation/Materials	Math Skills
• "How Big Are The Planets?" • Fact Book - Planets Summary of Facts • Graph Paper • Planet Cards (Optional)	• Rounding and Comparing Large Numbers • Graphing Data

During class:

- Use the Fact Book to look up and record the diameters of the planets. Discuss the wide range of sizes of the diameters and therefore of the planets themselves.

- Round the diameters to the nearest thousand and compare the planets in terms of the sizes of their diameters.

- Graph the rounded diameters on a bar graph.

- Discuss:
  - Which planet is the largest?...the smallest?
  - Which planets are about the same size?
  - Is there a relationship between the diameter of a planet and the speed at which it is travelling in its orbit?

Extensions
- "How Fast?!"
- Problem Cards: #3, 4

Name ______________________

HOW *BIG* ARE THE PLANETS?

OUR SOLAR SYSTEM

	Diameter (in miles)	Rounded Diameters (in thousands of miles)
Mercury		
Venus		
Earth		
Mars		
Jupiter		
Saturn		
Uranus		
Neptune		
Pluto		

Name ____________

HOW *BIG* ARE THE PLANETS?

OUR SOLAR SYSTEM

	Diameter (in miles)	Rounded Diameters (in thousands of miles)
Mercury	3031	3 thousand
Venus	7521	8 thousand
Earth	7921	8 thousand
Mars	4197	4 thousand
Jupiter	88,733	89 thousand
Saturn	74,600	75 thousand
Uranus	31,600	32 thousand
Neptune	30,200	30 thousand
Pluto	2113	2 thousand

Name ____________

HOW FAST?!?

ORBITAL SPEED IS THE SPEED AT WHICH A PLANET TRAVELS IN ITS ORBIT AROUND THE SUN.

	Orbital Speed in M.P.H.	Rounded Speed in thousands of M.P.H.
Mercury	107,300	107,000
Venus	78,500	79,000
Earth	66,500	66,000
Mars	54,100	54,000
Jupiter	29,300	29,000
Saturn	21,600	22,000
Uranus	15,300	15,000
Neptune	12,200	12,000
Pluto	10,600	11,000

1. Which planet's orbital speed is.....

fastest? Mercury
slowest? Pluto
more than earth's? Venus, Mercury

2. Graph the speeds of the planets on a bar graph.

3. The length of a planet's year is the time it takes that planet to orbit once around the sun.

Mercury's year is 88 days. It takes 88 days for Mercury to orbit the sun. The distance travelled by Mercury during one orbit is about 220,000,000 miles.

$$\begin{array}{r} 88 \text{ days} \\ \times\ 24 \text{ hours} \\ \hline 2112 \text{ hours} \end{array} \qquad \begin{array}{r} 107,300 \\ \times\ 2\,112 \\ \hline \end{array} \approx \begin{array}{r} 110,000 \\ \times\ 2000 \\ \hline 220,000,000 \text{ miles} \end{array}$$

Name ______________________

HOW FAST?!?

ORBITAL SPEED IS THE SPEED AT WHICH A PLANET TRAVELS IN ITS ORBIT AROUND THE SUN.

	Orbital Speed in M.P.H.	Rounded Speed in thousands of M.P.H.
Mercury		
Venus		
Earth		
Mars		
Jupiter		
Saturn		
Uranus		
Neptune		
Pluto		

1. Which planet's orbital speed is.....
fastest? ____________________
slowest? ____________________
more than earth's? _____________

2. Graph the speeds of the planets on a bar graph.

3. The length of a planet's year is the time it takes that planet to orbit once around the sun.

Mercury's year is 88 days. It takes 88 days for Mercury to orbit the sun. The distance travelled by Mercury during one orbit is about __________________.

HOW FAR IS PLUTO?
HOW NEAR IS MARS?

Preparation/Materials	**Math Skills**
- Review "Calculating with Rounded Numerals" in the Fact Book. - "How Far is Pluto?...How Near is Mars?" - "Summary of Facts," Fact Book.	- Estimation in Computation

During class:

- Introduce the lesson by solving a problem with the class from "How Far is Pluto?...How Near is Mars?"

- Point out to students that we can simplify the calculations if we use rounded numerals. Explain that the solutions are approximate rather than exact. However, for the purposes of these questions, approximate solutions are sufficient.

- Ask students to work individually or in a group to solve the problems posed.

- You may want to allow some students to use a calculator in order to perform the calculations on the rounded numerals.

Extensions

- "Astronomical Units"
- "Learning More About Our Solar System"
- Problem Cards: #2, 5, 6, 7, 8, 11, 12, 21, 25.

Name ______________________

HOW FAR IS PLUTO? HOW NEAR IS MARS?

Who am I?

1. I'm about 50 million miles further from the sun than the Earth. I'm ______________

2. I'm one billion fewer miles from the sun than Neptune. I'm ______________

3. My diameter is forty thousand miles larger than Uranus' diameter. I'm ______________

4. If Uranus, Neptune, Mars, Mercury, and Venus were placed side by side, they would have a combined diameter the length of my diameter. I'm ______________

5. We are two planets whose diameters differ by about 1,000 miles. We're ______________

6. I'm approximately 100 times as far from the sun as Mercury. I'm ______________

7. My orbital speed is twice as fast as Mars' speed. I'm ______________

8. Make up one yourself. Solve it. I'm ______________

What do you know about me?

9. I'm Mars.
How many times larger is my diameter than Earth's diameter? ______________

10. I'm the planet nearest to the sun.
How much closer am I to the sun than Saturn? ______________

11. I'm Mars.
How many times further from the sun is Jupiter? ______________

12. I'm Earth.
Planets closest to me in size are... ______________
Planets that are more than ten times further from the sun than I am are ______________

13. I'm Uranus.
How many times faster must I travel to travel at the same orbital speed as Venus? ______________

Make up your own

14. Use the back of this sheet to list the fact and question for your problem.

Name ______________________

HOW FAR IS PLUTO? HOW NEAR IS MARS?

Who am I?

1. I'm about 50 million miles further from the sun than the Earth. I'm Mars
2. I'm one billion fewer miles from the sun than Neptune. I'm Uranus
3. My diameter is forty thousand miles larger than Uranus' diameter. I'm Saturn
4. If Uranus, Neptune, Mars, Mercury, and Venus were placed side by side, they would have a combined diameter the length of my diameter. I'm Saturn
5. We are two planets whose diameters differ by about 1,000 miles. We're Mercury & Mars
6. I'm approximately 100 times as far from the sun as Mercury. I'm Pluto
7. My orbital speed is twice as fast as Mars' speed. I'm Mercury
8. Make up one yourself. Solve it. I'm ______________

What do you know about me?

9. I'm Mars.
   How many times larger is my diameter than Earth's diameter? about 2 times
10. I'm the planet nearest to the sun.
    How much closer am I to the sun than Saturn? 850,000,000
11. I'm Mars.
    How many times further from the sun is Jupiter? about 3½ times
12. I'm Earth.
    Planets closest to me in size are... Venus
    Planets that are more than ten times further from the sun than I am are Uranus, Neptune, Pluto
13. I'm Uranus.
    How many times faster must I travel to travel at the same orbital speed as Venus? about 5 times

Make up your own

14. Use the back of this sheet to list the fact and question for your problem.

Regional Math Network • Harvard Graduate School of Education • Harvard University

---

Name ______________________

HOW FAR IS PLUTO?... HOW NEAR IS MARS?...

15. Find the distance "through the earth" from the North to the South Pole. Write the distance in rounded terms.	15. Actual = 7927 mi Rounded = 8000 mi
16. How many times farther away from the sun is Jupiter than Mercury?	16. ≈ 3.5 times
17. How many times farther away from the sun is Pluto than Mars?	17. ≈ 26 times
18. Is the distance of Neptune from the sun more or less than four times the distance of Jupiter from the sun? Show your reasoning.	18. more
19. Each day about 5 million kilograms of cosmic dust settle on the earth's surface. A kilogram is about 2.2 lbs. Does more or less than ten tons of dust settle each day?	19. more
20. Create a problem for a classmate.	20.

Regional Math Network • Harvard Graduate School of Education • Harvard University

Name ____________________

HOW FAR IS PLUTO?...
HOW NEAR IS MARS?...

15. Find the distance "through the earth" from the North to the South Pole. Write the distance in rounded terms.	15. Actual = ____________ Rounded = ____________
16. How many times farther away from the sun is Jupiter than Mercury?	16.
17. How many times farther away from the sun is Pluto than Mars?	17.
18. Is the distance of Neptune from the sun more or less than four times the distance of Jupiter from the sun? Show your reasoning.	18.
19. Each day about 5 million kilograms of cosmic dust settle on the earth's surface. A kilogram is about 2.2 lbs. Does more or less than ten tons of dust settle each day?	19.
20. Create a problem for a classmate.	20.

Name ______________________

ASTRONOMICAL UNITS

THE DISTANCES IN SPACE ARE SO GREAT THAT SCIENTISTS NEED UNITS GREATER THAN MILES TO MEASURE OR DESCRIBE THEM.

THE UNIT THAT SCIENTISTS AGREED UPON IS AN ASTRONOMICAL UNIT (AU).

ONE ASTRONOMICAL UNIT IS EQUAL TO 93 MILLION MILES, THE DISTANCE BETWEEN THE EARTH AND THE SUN.

1. Comets spend most of their time in the Oort cloud, which stretches from 20,000 to 100,000 astonomical units from the sun.

   Approximately how far away from the sun is the farthest comet? 9.3 trillion miles

   Approximately how far away from sun is the closest comet? 1.86 trillion miles

2. Express the distances of the "outer" planets from the sun in terms of astronomical units:

   Pluto: 39.5 AU

   Uranus: 19.1 AU

   Neptune: 30 AU

   Jupiter: 5.2 AU

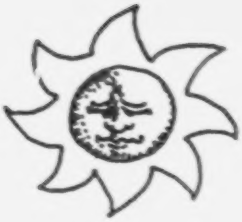
   Saturn: 9.5 AU

3. On a map of the universe, let one inch represent one AU. How many inches would represent the distance from Jupiter to the Sun?

   5.2"

4. If one inch represents one AU, then 39.44 inches represents the location of what planet? Pluto

Name ____________________



ASTRONOMICAL UNITS

THE DISTANCES IN SPACE ARE SO GREAT THAT SCIENTISTS NEED UNITS GREATER THAN MILES TO MEASURE OR DESCRIBE THEM.

THE UNIT THAT SCIENTISTS AGREED UPON IS AN ASTRONOMICAL UNIT (AU).

ONE ASTRONOMICAL UNIT IS EQUAL TO 93 MILLION MILES, THE DISTANCE BETWEEN THE EARTH AND THE SUN.

1. Comets spend most of their time in the Oort cloud, which stretches from 20,000 to 100,000 astonomical units from the sun.

   Approximately how far away from the sun is the farthest comet?____________

   Approximately how far away from sun is the closest comet?____________

2. Express the distances of the "outer" planets from the sun in terms of astronomical units:

   Pluto: ____________________ AU

   Uranus: ____________________ AU

   Neptune: ____________________ AU

   Jupiter: ____________________ AU

   Saturn: ____________________ AU

3. On a map of the universe, let one inch represent one AU. How many inches would represent the distance from Jupiter to the Sun?

   ____

4. If one inch represents one AU, then 39.44 inches represents the location of what planet?____________

Name ______________________

LEARNING MORE ABOUT OUR SOLAR SYSTEM

Because we are often talking about stars in our solar system, we often think about the speed of light. The speed of light is 186,300 miles per second.

1. How many seconds are there in one year?

60 sec = 1 min
3600 sec = 1 hour
86,400 sec = 1 day

31,536,000 sec = 1 year

2. About how many miles are there in a light-year? __________ **(A *light-year* is the number of miles light travels in one year.)**

$$\begin{array}{r} 31{,}536{,}000 \\ \times\ 186{,}300 \\ \hline \end{array} \approx \begin{array}{r} 30{,}000{,}000 \\ 200{,}000 \\ \hline 6{,}000{,}000{,}000{,}000 \end{array} \text{ mi.}$$

3. The next nearest star beyond the sun is about four light-years away from the sun. About how far is it in miles?

$$\begin{array}{r} 6{,}000{,}000.000{,}000 \\ \times 4 \\ \hline 24{,}000{,}000{,}000{,}000 \end{array} \text{ mi.}$$

4. Our solar system is about 3 x 10^5 light years away from the center of the Milky Way. About how far is this in miles?

$3 \times 10^5 = 30{,}000$

$$\begin{array}{r} 6{,}000{,}000{,}000{,}000 \\ \times\ 30{,}000 \\ \hline 180{,}000{,}000{,}000{,}000{,}000 \end{array} \text{ mi.}$$

Name ____________________

LEARNING MORE ABOUT OUR SOLAR SYSTEM

Because we are often talking about stars in our solar system, we often think about the speed of light. The speed of light is 186,300 miles per second.

1. How many seconds are there in one year?

2. About how many miles are there in a light-year? __________
(**A *light-year* is the number of miles light travels in one year.)**

3. The next nearest star beyond the sun is about four light-years away from the sun. About how far is it in miles?

4. Our solar system is about 3×10^5 light years away from the center of the Milky Way. About how far is this in miles?

LET'S PRETEND...

Preparation/Materials

- "What if the Earth Were 1" in Diameter?"
- Sphere 1" in diameter
- Spheres of various sizes (Optional)

Math Skills

- Scale Drawing and Scale Models
- Ratio and Proportion
- Rounding and Comparing Large Numbers

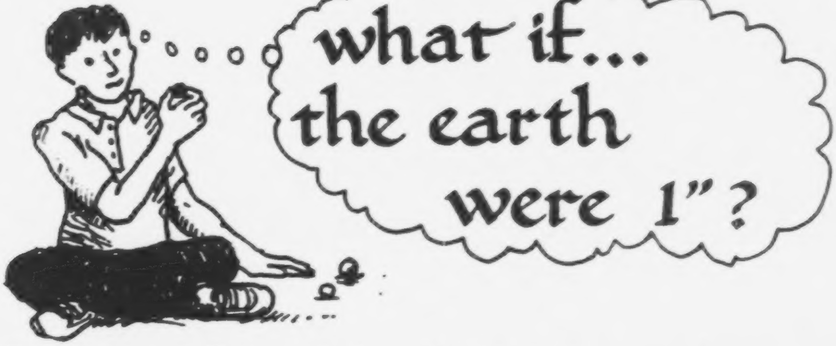
During class:

- Pose the following question:
  "If the earth is a sphere with a 1" diameter, what size sphere could be used to represent the moon?...the sun?"
- Brainstorm with the class about techniques which could be used to make a scale model of the moon and sun.
- Teach ratio techniques to make scale models, using rounded numerals to describe the diameters of the sun and moon.
- Introduce distance with the following question:
  Using the same scale of miles to inches and holding the earth in your hands, how far away would the sun and the moon be from you?
- Use objects in the environment to describe the sizes of and distances between the earth, moon, and sun so that they become real to the students. For example, if the earth were in the classroom, the moon would be "at the drugstore."

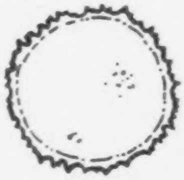
Extensions

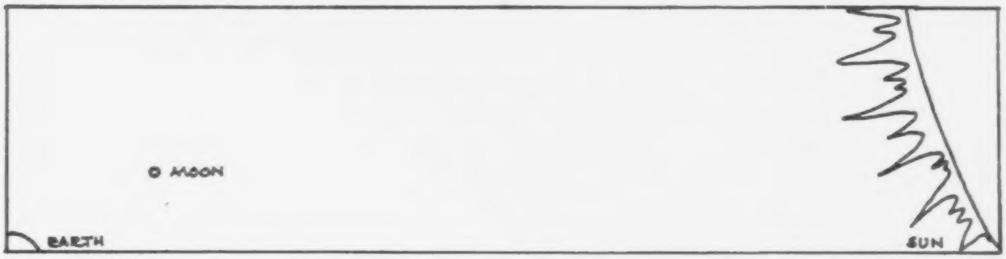
- "Think of the Earth as a Ball"
- Problem Cards #13, 15

Name________________________


what if...
the earth
were 1"?

What would models of the sun and moon look like?

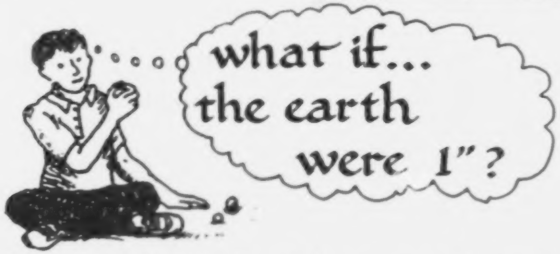
	Earth	Moon	Sun
Diameter in miles:			
Rounded diameter in thousands of miles:			
Scaled diameter:	1"		



How far apart are they if 1" is about 8 thousand miles?

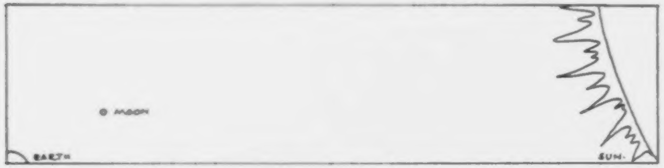
Distances between:	Actual	Rounded	Scaled (1" = 8000 mi)
Earth and Moon			IN. FT.
Earth and Sun			IN. FT.

Name ____________


what if...
the earth
were 1"?

What would models of the sun and moon look like?

	Earth	Moon	Sun
Diameter in miles:	 7927	 2160	 865,000
Rounded diameter in thousands of miles :	8000	2000	865,000
Scaled diameter :	1"	1/4"	108"



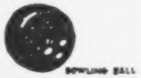
How far apart are they if 1" is about 8 thousand miles?

Distances between:	Actual	Rounded	Scaled (1" = 8000 mi)
Earth and Moon	238,900	239,000	30 IN. 2.5 FT.
Earth and Sun	92,900,000	93,000,000	11,625 IN. 969 FT.

Name ____________

THINK OF THE EARTH AS A BALL

Think about the Earth, Moon and Sun in terms of balls we know.

 BILLIARD BALL Diameter is about 2.2"	 TENNIS BALL Diameter is about 2.5"	 BASKETBALL Diameter is about 9.6"
 BASEBALL Diameter is about 2.8"	 SOCCER BALL Diameter is about 8.6"	 SHOT PUT Diameter is about 4.7"
 GOLF BALL Diameter is about 1.7"	 VOLLEY BALL Diameter is about 8.3"	 BOWLING BALL Diameter is about 8.6"

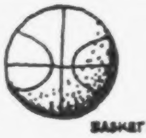
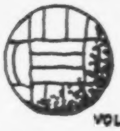
(Note: dimensions are correct, but proportions of drawings are not to scale.)

If :		It would look like :
Earth were a soccer ball...	the Moon's approximate diameter would be 2.3".	billiard ball
Earth were a basketball...	the Moon's approximate diameter would be 2.6".	tennis ball
Moon were a billiard ball...	the Earth's approximate diameter would be 8.1".	volley ball
Earth were a golf ball...	the Sun's approximate diameter would be 185".	
Earth were a soccer ball...	the Moon's approximate diameter would be 2.4".	—

Name ______________________

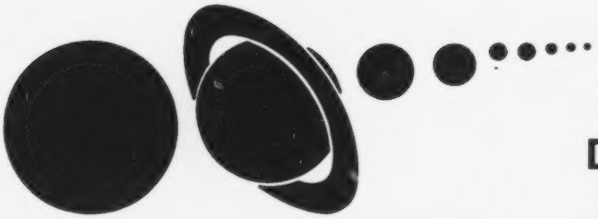
THINK OF THE EARTH AS A BALL

Think about the Earth, Moon and Sun in terms of balls we know.

 BILLIARD BALL Diameter is about 2.2"	 TENNIS BALL Diameter is about 2.5"	 BASKETBALL Diameter is about 9.6"
 BASEBALL Diameter is about 2.8"	 SOCCER BALL Diameter is about 8.6"	 SHOT PUT Diameter is about 4.7"
 GOLF BALL Diameter is about 1.7"	 VOLLEY BALL Diameter is about 8.3"	 BOWLING BALL Diameter is about 8.6"

(Note: dimensions are correct, but proportions of drawings are not to scale.)

If:		It would look like:
Earth were a soccer ball...	the Moon's approximate diameter would be ____".	
Earth were a basketball...	the Moon's approximate diameter would be ____".	
Moon were a billiard ball...	the Earth's approximate diameter would be ____".	
Earth were a golf ball...	the Sun's approximate diameter would be ____".	
Earth were a ________...	the Moon's approximate diameter would be 2.4".	



LET'S EXTEND... BRINGING THE PLANETS DOWN TO EARTH'S SCALE

Preparation/Materials	Math Skills
• "Sizing Up the Planets" • "Create a Model of theSolar System" • Review Fact Book - Summary of Facts • Sphere 1" in diameter • Spheres of Various Sizes (Optional)	• Rounding and Comparing Large Numbers • Scale Drawing and Scale Models • Ratio and Proportion

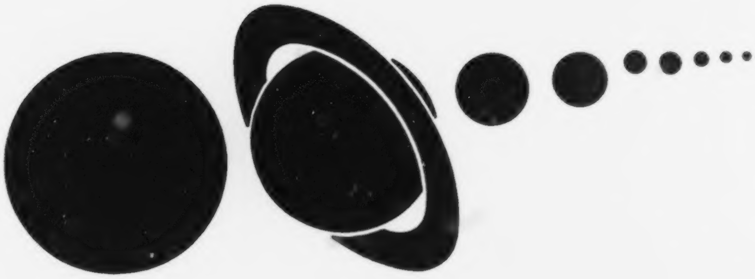
During class:

- Pose a challenge to the students: "Can we build a model of the solar system in our school?"
- Holding a 1" sphere, ask the students: "If the earth were a 1" sphere like this, what would the size of the other planets be and where would they be located?"
- Determine the size of spheres needed to represent the other planets, using ratio and proportion techniques. Record the results on "Sizing Up the Planets."
- Find the scaled distance each planet would be from the sun. Record the results on "Create a Model of the Solar System."
- These activities are quite time consuming if each student completes each task individually. To assemble the data more quickly:
    - Divide the class into nine groups, with each group responsible for one planet.
    - Assign portions of the task for homework.
- Discuss the fact that distances are too large to be translated into meaningful terms because they are bigger than distances we know.
- Brainstorm other ways to express distance. Encourage the students to think of distances in terms of the time it takes to travel.

Extensions

- Compare the relative locations of the planets to locations in the community. For example, if the sun were in the classroom, Mercury might be at the drugstore and Pluto in the next town.

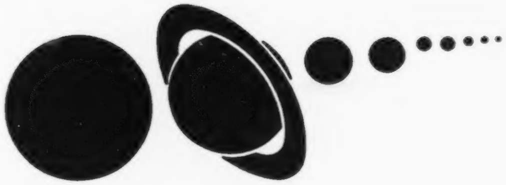
Name ______________________



SIZING UP THE OTHER PLANETS

DIAMETER			
	(in miles)	Rounded (in thousands of miles)	Scaled
Mercury			
Venus			
Earth			1"
Mars			
Jupiter			
Saturn			
Uranus			
Neptune			
Pluto			

Name ____________________

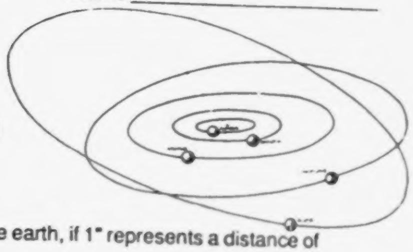


SIZING UP THE OTHER PLANETS

DIAMETER			
	(in miles)	Rounded (in thousands of miles)	Scaled
Mercury	3031	3000	$\frac{3}{8}$"
Venus	7521	8000	1"
Earth	7929	8000	1"
Mars	4197	4000	$\frac{1}{2}$"
Jupiter	88,733	89,000	11"
Saturn	74,600	75,000	9"
Uranus	31,600	32,000	4"
Neptune	30,200	30,000	3.8"
Pluto	2113	2000	$\frac{1}{4}$"

Name ____________________

CREATE A MODEL OF THE SOLAR SYSTEM



How far are the moon and sun from the earth, if 1" represents a distance of 8,000 miles?

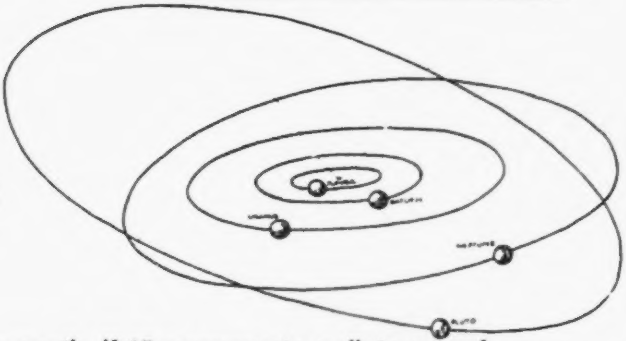
Distance between	in Miles	Rounded in Millions of Miles	Scaled (1" = 8000 mi.)
Earth and Moon	238,900	.2	30 "
Earth and Sun	92,963,115	93,000,000	11,625"

How far from the Sun are the other planets? (Use the table of Approximate Distances Between Planets in Fact Book)

DISTANCE FROM SUN			
	in Miles	Rounded in Millions of Miles	Scaled (1"= 8000 mi.)
Mercury	35,980,103	36,000,000	4500"
Venus	67,240,115	67,000,000	8375"
Mars	141,642,351	142,000,000	17,750"
Jupiter	483,625,103	484,000,000	60,500"
Saturn	890,613,004	891,000,000	111,375"
Uranus	1,782,020,003	1,782,000,000	222,750"
Neptune	2,794,444,010	2,794,000,000	349,250"
Pluto	3,654,410,091	3,654,000,000	456,750"

Name ____________________

CREATE A MODEL
OF
THE SOLAR SYSTEM



How far are the moon and sun from the earth, if 1" represents a distance of 8,000 miles?

Distance between	in Miles	Rounded in Millions of Miles	Scaled (1" = 8000 mi.)
Earth and Moon			
Earth and Sun			

How far from the Sun are the other planets? (Use the table of Approximate Distances Between Planets in Fact Book)

DISTANCE FROM SUN

	in Miles	Rounded in Millions of Miles	Scaled (1"= 8000 mi.)
Mercury			
Venus			
Mars			
Jupiter			
Saturn			
Uranus			
Neptune			
Pluto			

LET'S TRY IT...
TRAVELLING ON EARTH

Preparation/Materials	Math Skills
• "Let's Take a Trip" • Globe • Calculators (Optional)	• Use of formula: D = RT • Circumference • Conversion of Units

During class:

- Describe various modes of travel:
    - walking, average speed 4 mph;
    - bicycling, average speed 10 mph;
    - automobile, average speed 55 mph;
    - jet, 650 mph.

- Using a globe explore various paths to travel "around" the earth.
  Point out that the distance at the equator represents a reasonable length for us to consider as the length of our trip "around" the earth.

- Define distance around the earth as the circumference of the great circle of the equator and review the formula for circumference of a circle,

$$\textbf{Circumference} = \pi \text{ times } \textbf{Diameter}$$

$$C = \pi D$$

- Discuss informally the relationship of **Distance = Rate** times **Time**.

$$D = RT$$

- Ask students to find the length of the trip they are to travel "around" the earth and then calculate how long it would take using one of the vehicles described.

- Encourage the students to use rounded numerals for distances and to express their solutions in approximate terms.

Extensions

- Compute and compare the times of trips using various modes of transportation. The Fact Book includes Measurement Trivia, which includes other speeds of interest.
- "More Trips"
- Problem Card # 20
- Journal Entry: Write about your trip around the earth, the vehicle you chose, what you saw, problems you met.

Name ____________________

LET'S TAKE A TRIP

Where shall we go?

How Long Will It Take?

	Average Speed			
	Walking 4 mph	Bicycling 10 mph	By Car 55 mph	By Jet 650 mph
A Trip to California's Disneyland from Boston Distance = 3294 mi.				
A Trip "around" Earth Distance = 25,120 mi.				
A Trip "around" Moon Distance = 6,280 mi.				
A Trip "around" ___with Distance = 235,000 mi. The planet is:				
Your Choice: A Trip "around" .... with Distance "around" it =				

SOME USEFUL FORMULAE

$C = \pi \cdot D$

Circumference = π times Distance

$D = R \cdot T$

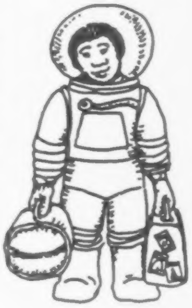
Distance = Rate times Time

Name ____________________

LET'S TAKE A TRIP

How Long Will It Take?

Where shall we go?



	Average Speed			
	Walking 4 mph	Bicycling 10 mph	By Car 55 mph	By Jet 650 mph
A Trip to California's Disneyland from Boston Distance = 3294 mi.	≈ 824 hrs	329 hrs.	60 hrs.	5 hrs.
A Trip "around" Earth Distance = 25,120 mi.	6280 hrs.	2512 hrs.	457 hrs.	39 hrs.
A Trip "around" Moon Distance = 6,280 mi.	1570 hrs.	628 hrs.	114 hrs.	9.6 hrs.
A Trip "around" ___ with Distance = 235,000 mi. The planet is: Saturn	58,750 hrs	23,500 hrs	4273 hrs.	361.5 hrs
Your Choice: A Trip "around" .... with Distance "around" it =				

SOME USEFUL FORMULAE

$C = \pi \cdot D$
Circumference = π times Distance

$D = R \cdot T$
Distance = Rate times Time

Regional Math Network • Harvard Graduate School of Education • Harvard University

---

Name ____________________

MORE TRIPS....

	Orbiter Speed= 25,780 m.p.h.	US/German Orbiter Speed = 149,125 m.p.h.	Light Speed= 186,000 m.p.sec.
A Trip to California's Disneyland from Boston Distance = 3294 mi.	.13 hrs.	.02 hrs.	.02 sec.
A Trip "around" Earth Distance = 25,120 mi.	.97 hrs.	.17 hrs.	.14 sec
A Trip "around" Moon Distance = 6,280 mi.	.24 hrs.	.04 hrs.	.03 sec.
A Trip "around" ___ with Distance = 235,000 mi. The planet is:	9 hrs.	1.6 hrs.	1.3 sec.
Your Choice: A Trip "around" .... with Distance "around" it =			

SOME USEFUL FORMULAE

$C = \pi \cdot D$
Circumference = π times Distance

$D = R \cdot T$
Distance = Rate times Time

Regional Math Network • Harvard Graduate School of Education • Harvard University

Name ____________

MORE TRIPS....

	Orbiter Speed= 25,780 m.p.h.	US/German Orbiter Speed = 149,125 m.p.h.	Light Speed= 186,000 m.p.sec.
A Trip to California's Disneyland from Boston Distance = 3294 mi.			
A Trip "around" Earth Distance = 25,120 mi.			
A Trip "around" Moon Distance = 6,280 mi.			
A Trip "around" ___with Distance = 235,000 mi. The planet is:			
Your Choice: A Trip "around" .... with Distance "around" it =			

SOME USEFUL FORMULAE

$C = \pi \cdot D$

Circumference = π times Distance

$D = R \cdot T$

Distance = Rate times Time

LET'S FLY IT...
TRAVELLING IN SPACE

Preparation/Materials	Math Skills
• "Let's Send Jesse to Pluto" • "Summary of Facts", Fact Book • "Distances Between Planets" • Calculator	• Use of Formula: D = RT • Conversion of Measures

During class:

- Pose the challenge:
  "Let's send Jesse to Pluto. How long will it take, if he is travelling in his anti-gravity VW bus at 55 mph?"

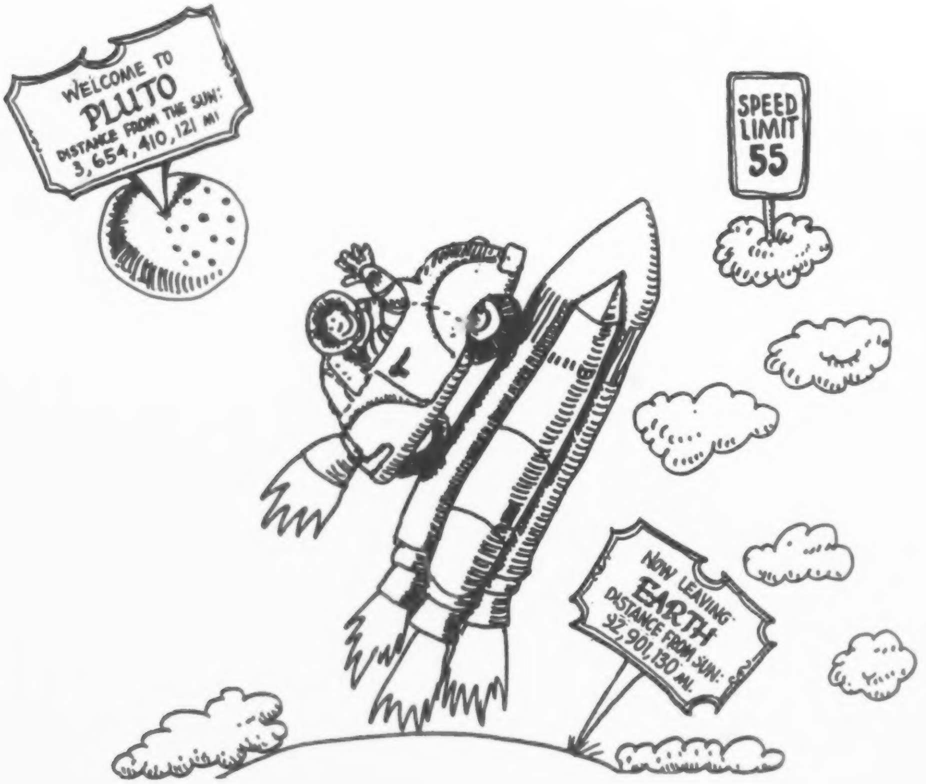
- Encourage students to work in groups.

- Help particular groups, if necessary, to recognize the tools they need to find a solution: using a table to find distances; rounding distances; D = RT relationship; and conversion of units of time. Describe possible solution strategies and steps.

- Discuss the intriguing dilemmas of space travel:
  - Time is the dilemma of long trips in space; planets constantly move in their orbit so the relative distance is always changing;
  - Trips in space must be planned to reach the location where the planet will be when the space ship arrives;
  - Space flights such as the Voyager plan for such "windows" of opportunity so that the course is calculated as the spacecraft flies rather than when the spacecraft takes off.

Extensions
- "Let's Fly It"
- "Inter-Planetary Space Agency"
- Choose a planet, collect information about it and imagine a "creature" who lives there. Plan a trip to the planet, including distance travelled, speed of travel, and length of trip.
- Problem Cards: #1, 9, 10, 16, 17, 23

Name ______________________________



Let's send Jesse to Pluto
Maybe he'll find intelligent life out there!

As a pre-flight trial, Jesse takes a test flight to the moon.

If he travels in his anti-gravity VW at 55 mph, how long will it take to get to the moon? Remember that the moon is 238,900 miles from the earth.

The test flight was a success.

How long will it take Jesse to travel from Earth to Pluto?

Name ______________________

Let's send Jesse to Pluto
Maybe he'll find intelligent life out there!

As a pre-flight trial, Jesse takes a test flight to the moon.

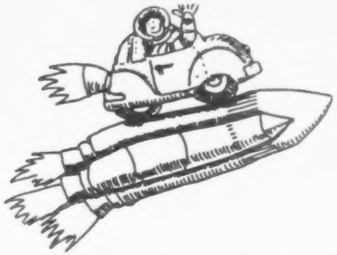
If he travels in his anti-gravity VW at 55 mph, how long will it take to get to the moon? Remember that the moon is 238,900 miles from the earth.

The test flight was a success. $\frac{240,000}{55} = 4363$ hours $\approx$ 182 days

How long will it take Jesse to travel from Earth to Pluto?

$\frac{3,560,000,000}{55} \approx 65,000,000$ hours $\approx$ 2,700,000 days

---



Name ______________________

LET'S FLY IT
TRAVELLING IN SPACE

We are now in a synodic period. That is, all planets are "lined up." The distances between planets during a synodic period are pictured and recorded in the Fact Book.

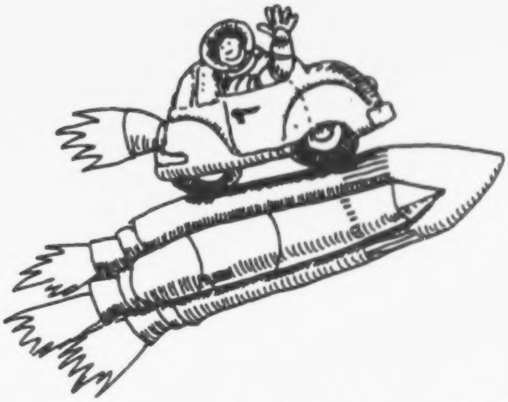
How long is a trip from...	Time of trip at shuttle speed 17,500 m.p.h.	Time of trip at US/German Orbiter speed 149,125 m.p.h.	Time of trip at speed of light 186,000 mi/sec.
Earth to Moon? Distance = 238,900 mi.	13.6 hrs.	1.6 hrs.	1.3 sec.
Earth to Mars? Distance = 48,679,236 mi.	2782 hrs.	326 hrs.	262 sec.
Earth to Pluto? (Jesse's Trip) Distance = 3,561,446,976 mi.	203,486 hrs.	≈ 23,880 hrs	19,145 sec.

1. Suppose your trip had the following itinierary: From Earth to the Moon to Mars, and then home. How far would you travel? ≈ 97,000,000 mi.

   Travelling at the speed of the Orbiter, how long would the trip take?

   ≈ 3774 hrs.

2. Plan a trip in the solar system. You'll start from Earth and visit three planets. On the back of this sheet, list the three planets, the total distance travelled, your speed and how long you will be away.



Name________________________

LET'S FLY IT
TRAVELLING IN SPACE

We are now in a synodic period. That is, all planets are "lined up." The distances between planets during a synodic period are pictured and recorded in the Fact Book.

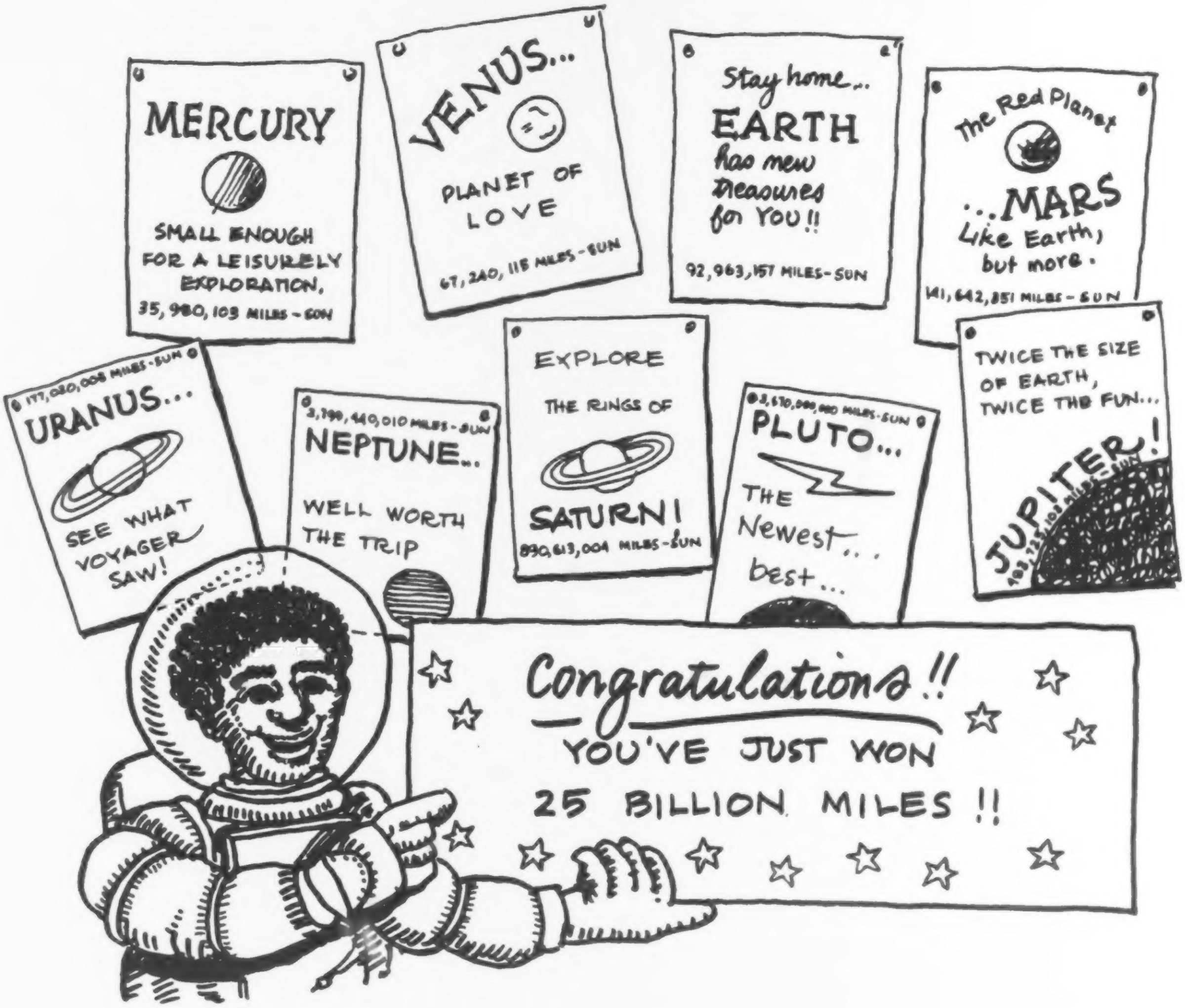
How long is a trip from...	Time of trip at shuttle speed 17,500 m.p.h.	Time of trip at US/German Orbiter speed 149,125 m.p.h.	Time of trip at speed of light 186,000 mi/sec.
Earth to Moon? Distance = 238,900 mi.			
Earth to Mars? Distance = 48,679,236 mi.			
Earth to Pluto? (Jesse's Trip) Distance = 3,561,446,976 mi.			

1. Suppose your trip had the following itinierary: From Earth to the Moon to Mars, and then home. How far would you travel?____________________

   Travelling at the speed of the Orbiter, how long would the trip take?

2. Plan a trip in the solar system. You'll start from Earth and visit three planets. On the back of this sheet, list the three planets, the total distance travelled, your speed and how long you will be away.

INTER PLANETARY SPACE AGENCY



WHAT IS YOUR ITINERARY?

the shuttle system

ACTIVITIES

MODULE III: **THE SPACE SHUTTLE**

The First Step of the Journey

Leaving Earth…Its Atmosphere and Beyond
All Aboard
The Shuttle…Let's Make It
Creative Blast-Off (Optional)
Orbiter Specs
"Sure It's Big…But Compared to What?"
Planning for Life on Board…Let's Eat
Planning for Life on Board…Let's Work
Planning for Life on Board…Let's Experiment
3,2,1 Blast-Off
Toys in Space (Optional)

LEAVING EARTH...
ITS ATMOSPHERES AND BEYOND

Preparation/Material	**Math Skills**
• Attach a string or tape from floor to ceiling in classroom. • "Leaving Earth..." • String • Topological Maps (Optional)	• Graping Data • Scale Models and Scale Drawing

During class:

- Ask students to locate a position on the string to indicate a proper altitude for the intercontinental flight of a jumbo jet aircraft. Students must decide an appropriate scale to use to locate a scaled height for the jet and to fit data given on chart.

- Discuss the many questions that arise:
  - What is the cruising altitude for a single engine prop plane? (approximately 2000')
  - ...for an executive jet? (approximately 15,000')
  - ...for a regularly schedule jet airliner? (approximately 30,000')

- Mark the height of the jumbo jet and then ask: "At what level did the X-15 fly? Plot it on the string."

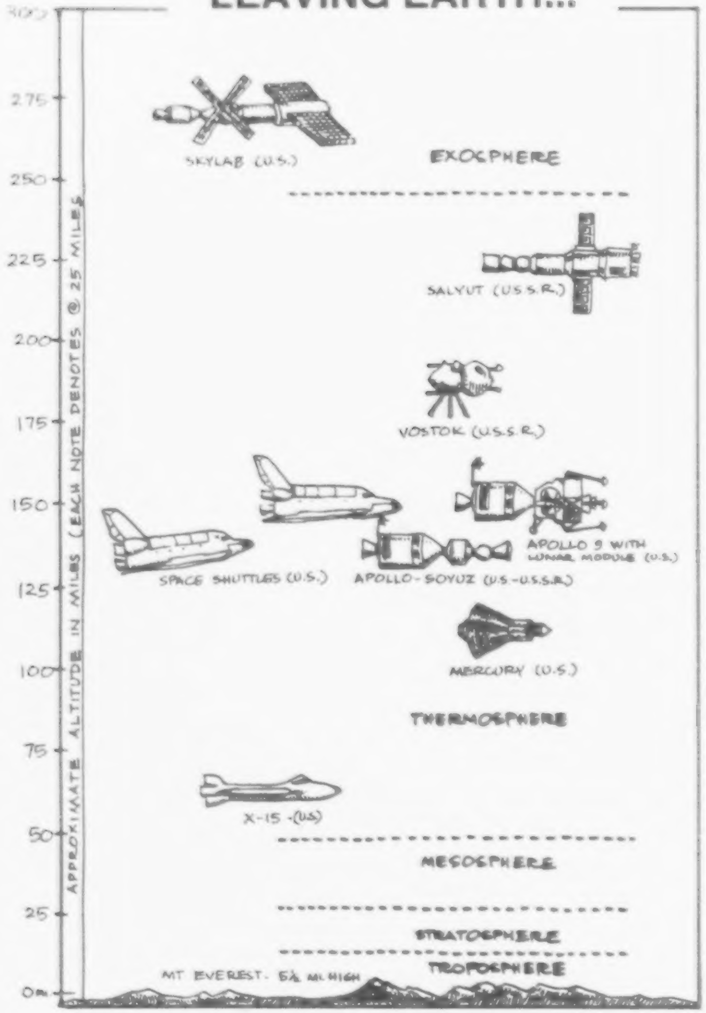
- Ask students to plot the position on the string to indicate the end of the troposphere, the stratosphere, the mesosphere, and thermosphere.

- Locate on the string the Mercury mission... The space shuttle... Apolio 9... Skylab.

Extensions

- Look up the origin and meaning of "troposphere," "stratosphere," etc.
- Explore Topological maps and how they represent heights.
- Plot height of local landmarks on string:
  Prudential Building, Blue Hills, Mount Washington.

LEAVING EARTH...

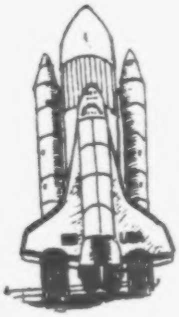


Earth's Atmospheres and Its Space Activity

Name ______________________

Suppose you were making a scale model of atmospheric activity. Attach a string from the floor to the ceiling. The floor represents Earth. What height on the string would represent each level of activity if 1" represents 3 miles?

	ACTUAL HEIGHT	HEIGHT ON STRING
MOUNT WASHINGTON		
MOUNT EVEREST TROPOSPHERE (FROM ________ TO ________)		
GEOSYNCHRONOUS ORBIT: The orbit whose speed is the same as the earth's, so that objects in it stay in their same relative position when viewed from earth.	21,400 mi.	
STRATOSPHERE (FROM ________ TO ________)		
MESOSPHERE (FROM ________ TO ________)		
THERMOSPHERE The range where most current space activity has occurred. (FROM ________ TO ________)		
EXOSPHERE Proposed location for Skylab (FROM ________ TO ________)		



ALL ABOARD

Preparation/Materials	Math Skills
• Select a Media Experience • Review "All You Need to Know About the Shuttle," in the Fact Book. • "Mission Control"	• Coordinate Graphing

During Class:

- Brainstorm with the students about the shuttle, shuttle missions and people who work on projects associated with the shuttle program.

  This discussion will provide a rich and interesting introduction to this module. A script for discussion which can be used with or without slides follows. Additional information about slides is available in the bibliography.

- Introduce the shuttle and shuttle missions using models, pictures and overheads found in the Fact Book.

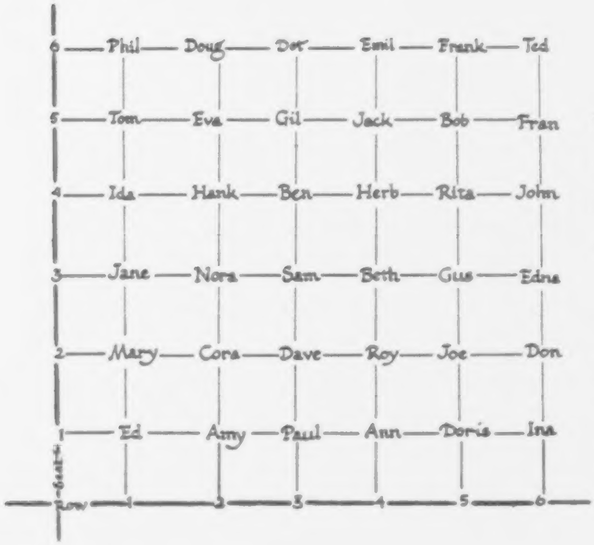
- Discussion Questions:
  - How large do you think the shuttle is?
  - How fast does it "go"?
  - What's it like inside?
  - What must it feel like, looking out?
  - Would you like to ride in it?
  - What would you like about such a ride?
  - What would you dislike about such a ride?

Extensions
- "All Aboard Coordinate Puzzle"
- Journal Entry:
  - If NASA called today, you would...
  - If you could only take one thing on the shuttle mission, what would it be?
  - Why might you not want to go?
- Ask teams of students to select a specific shuttle mission, research it and report to the class.

Name ____________________

MISSION CONTROL

During each shuttle mission, specialists and technicians at Johnson Space Center in Houston monitor all aspects of the astronauts' activities.



6	Phil	Doug	Dot	Emil	Frank	Ted
5	Tom	Eva	Gil	Jack	Bob	Fran
4	Ida	Hank	Ben	Herb	Rita	John
3	Jane	Nora	Sam	Beth	Gus	Edna
2	Mary	Cora	Dave	Roy	Joe	Don
1	Ed	Amy	Paul	Ann	Doris	Ina
Seat / Row	1	2	3	4	5	6

THE CHART ON THE LEFT SHOWS A PORTION OF THE SEATING PLAN AT MISSION CONTROL WITH THE NAMES OF THE SPECIALISTS ON DUTY.

IN THIS SEATING PLAN, DAVE SITS IN THE THIRD ROW, SECOND SEAT. THE NUMBER PAIR, (3,2) LOCATES DAVE'S POSITION.

1. WHO OCCUPIES THE SEAT NAMED BY THE NUMBER PAIR (2,3) ?

____

2. LOCATE THE POSITIONS OF THE FOLLOWING SPECIALISTS:

a. EVA __________ c. ROY __________ e. DOT __________

b. BOB __________ d. JOHN __________ f. INA __________

3. NAME THE SPECIALISTS WHOSE POSITIONS ARE NAMED BY THESE NUMBER PAIRS:

a. (4,3) __________ c. (6,3) __________ e. (5,2) __________

b. (1,5) __________ d. (3,5) __________ f. (2,6) __________

4. WRITE NUMBER PAIRS FOR ALL SPECIALISTS SITTING IN THE THIRD ROW:

____

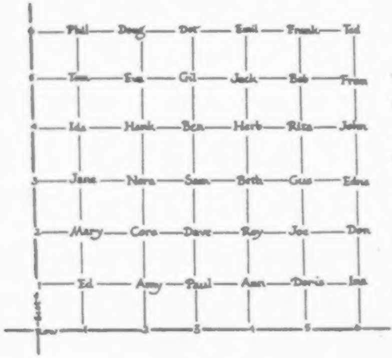
5. NAME THOSE SPECIALISTS WHOSE LOCATIONS ARE DESIGNATED BY NUMBER PAIRS SUCH THAT THE FIRST COORDINATE IS 2 MORE THAN THE SECOND COORDINATE.

____

Name ____________________

MISSION CONTROL

During each shuttle mission, specialists and technicians at Johnson Space Center in Houston monitor all aspects of the astronauts' activities.



THE CHART ON THE LEFT SHOWS A PORTION OF THE SEATING PLAN AT MISSION CONTROL WITH THE NAMES OF THE SPECIALISTS ON DUTY.

IN THIS SEATING PLAN, DAVE SITS IN THE THIRD ROW, SECOND SEAT. THE NUMBER PAIR, (3,2) LOCATES DAVE'S POSITION.

1. WHO OCCUPIES THE SEAT NAMED BY THE NUMBER PAIR (2,3) ?
   Nora

2. LOCATE THE POSITIONS OF THE FOLLOWING SPECIALISTS:

a. EVA 2,5	c. ROY 4,2	e. DOT 3,6
b. BOB 5,5	d. JOHN 6,4	f. INA 6,1

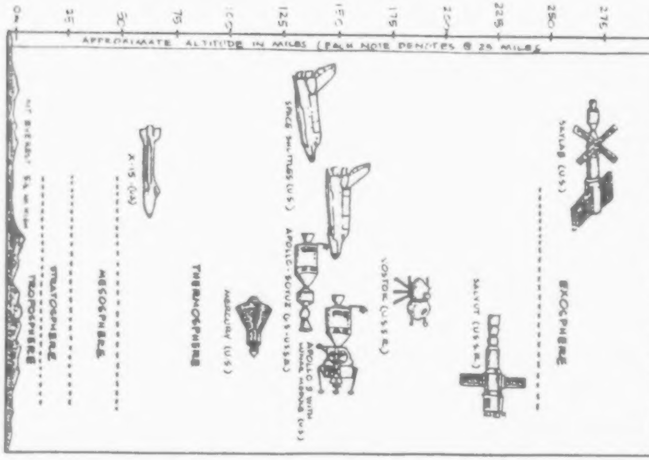
3. NAME THE SPECIALISTS WHOSE POSITIONS ARE NAMED BY THESE NUMBER PAIRS:

a. (4,3) Beth	c. (6,3) Edna	e. (5,2) Joe
b. (1,5) Tom	d. (3,5) Gil	f. (2,6) Doug

4. WRITE NUMBER PAIRS FOR ALL SPECIALISTS SITTING IN THE THIRD ROW:
   (3,1) (3,2) (3,3) (3,4) (3,5) (3,6)

5. NAME THOSE SPECIALISTS WHOSE LOCATIONS ARE DESIGNATED BY NUMBER PAIRS SUCH THAT THE FIRST COORDINATE IS 2 MORE THAN THE SECOND COORDINATE.
   Paul (3,1) Roy (4,2) Gus (5,3) John (6,4)

LEAVING EARTH...



Earth's Atmospheres and its Space Activity

Name ____________________

Suppose you were making a scale model of atmospheric activity. Attach a string from the floor to the ceiling. The floor represents Earth. What height on the string would represent each level of activity if 1" represents 3 miles?

	ACTUAL HEIGHT	HEIGHT ON STRING
MOUNT WASHINGTON	6288 ft.	≈ .4 in
MOUNT EVEREST TROPOSPHERE (FROM 0 TO ≈13 mi)	≈13 mi	≈ 4 in.
GEOSYNCHRONOUS ORBIT The orbit whose speed is the same as the earth's, so that objects in it stay in their same relative position when viewed from earth	21,400 mi.	≈ 7133 in.
STRATOSPHERE (FROM ≈ 12.5 mi TO ≈ 25 mi)	25 mi.	≈ 8 in.
MESOSPHERE (FROM ≈ 25 mi. TO ≈ 50 mi.)	50 mi.	≈ 17 in
THERMOSPHERE The range where most current space activity has occurred (FROM ≈ 50 mi. TO ≈ 248 mi.)	248 mi	≈ 83 in.
EXOSPHERE Proposed location for Skylab (FROM ≈ 248 mi. TO —)	248 mi +	≈ 83 in. +

ALL ABOARD
DISCUSSION SUGGESTIONS

The following dialogue presents an introduction to the various aspects of the current space shuttle system. The dialogue can either be read directly or embellished upon, depending upon the individual teacher's style. The dialogue does not depend upon the use of the slides. However, an effort has been made to suggest the slides that could accompany the respective dialogue.

	Slide Description	Dialogue
1)	Gemini rocket launch	The next topic in our investigation of outer space is spaceships: rockets with specially designed space capsules which allow astronauts to travel through space. The farthest any human has travelled until now is the moon. In 1969, three men landed and walked on the surface of the moon. It took them three days to travel to the moon and they spent only 21 hours on the moon surface; in all, they spent 8 days, 3 hours and 18 minutes in space.
2)	Apollo 11 astronaut on the moon	
3)	Apollo 11 astronaut descending lunar module ladder	
4)	Astronaut Bob Crippen on treadmill	Astronauts come in all shapes and sizes. Some are runners, some are floaters, some are black, some are white, some are men, some are women. NASA (National Aeronautics and Space Administration) is the US space agency which selects astronauts for space missions. According to NASA here are some of the requirements for being an astronaut: * under 6 feet tall * excellent physical condition * college degree * three years work experience
5)	Astronaut Bob Crippen floating in cabin	
6)	Astronaut Ron McNair playing saxophone	
7)	Bruce McCandless in Manned Maneuvering Unit	
8)	Unknown astronaut ready for medical experiments	
9)	Astronaut Sally Ride	
10)	Orion Nebula	The one thing all astronauts have in common is their curiosity about outer space. They are fascinated by it. They wonder what is out there on those little twinkling dots of light. Is there life on them? Is there a planet like Earth? How did those stars get there? Their questions are endless. Their curiosity drives them to search for the answers.
11)	Earth viewed from space	

Slide Description	Dialogue
12) Whirlpool galaxy in Canes Venatici	And one of the reasons why space is so interesting is that it is a virtual time machine. When we look at the stars in the sky we are looking back in time. The sun is 93 million miles away from Earth. This distance is so great that it takes the light from the sun **8 minutes** to get here. So when we look at the sun in the sky, we are really seeing light that is 8 minutes old - or we are seeing the sun as it was 8 minutes ago. The nearest star to Earth is trillions of miles away and it takes the light from that star many thousands of years to get here. So when we look at the star in the night sky, we are seeing the star as it was thousands of years ago. We are looking back in time. Mathematicians, scientists, and astronomers hope that by travelling in space to distant planets and stars we can answer the fundamental questions about the forming of the universe.
13) Tarus Nebula	
14) Shuttle main engine ignition	The Space Shuttle was built to travel to outer space. However, the shuttle has one large limitation: it cannot travel to other planets - not even to the moon - because of the limited amount of fuel it can carry. In the future, NASA hopes to modify the shuttle to be able to travel to other planets, but for now the shuttle only operates in Earth orbit.
15) Shuttle Challenger in orbit	
16) Apollo 11 launch	The shuttle was built for one major reason: to make space travel worth the money. In the 1960's, NASA built the Apollo space craft to take men to the moon. The cost of one Apollo space ship was about 2 million dollars. One Space Shuttle costs 3 million dollars and takes over 2 years to build. But unlike the Apollo, the shuttle was designed to travel into space 100 times; the Apollo only once. Since the shuttle can go into space more than once, the cost of each flight is cheaper than ever before.
17) Shuttle Columbia landing at Edwards Air Force Base in Calif.	
18) Shuttle Columbia on launch pad	As the shuttle sits on the launch pad, you can see the three main parts of the shuttle system: the shuttle itself (called the ORBITER), the large external tank below the orbiter, and the two solid rocket boosters strapped to the sides of the external tank.

Slide Description	Dialogue
	The shuttle system might not look too big when you look at this slide. In fact, the shuttle is one of the shortest space crafts ever built. The total length of the system from the bottom of the booster rockets to the top of the external tank is 184 feet. The Prudential Building in downtown Boston is over 800 feet tall and has 50 stories in all, which means the shuttle is about the height of a 13 story building.
19) Shuttle Columbia launch	The Solid Rocket Boosters (SRB's), the tall white rockets on the side of the large tank, provide the majority of the thrust needed to get the shuttle off the ground. The combined thrust of the SRB's is over 6,000,000 lbs., which is enough thrust to get 25 jumbo 747 jet airliners off the ground. Imagine all of this power from rockets that are only 12 feet in diameter.
	The external tank, the large tank under the orbiter, is essentially a big gas tank. The purpose of the tank is to hold the liquid fuel for the 3 main rocket engines on the back of the orbiter. And when we say this is a big tank we mean a **BIG TANK** : at lift-off it contains 140,000 gallons of liquid hydrogen and 380,000 gallons of liquid oxygen - a combined total of 520,000 gallons of liquid fuel - enough to fill 18 swimming pools.
	One of the most interesting aspects of a shuttle launch is the countdown. But have you ever stopped to think why we need a countdown? Why don't we just count to 3 and say "Go"? Well the shuttle countdown starts long before the count of 3; in fact it begins 40 hours before launch. The countdown is needed to coordinate all of the complex shutttle launch systems.
20) Astronaut in pilot seat (computer monitors can be seen in front of the astronaut)	On board the shuttle, there are 4 computers that control the final stages of the countdown. All the computers work independently of each other making the calculations needed for launch. As a safety precaution, all of the computers cross check their operation with one another and if they do not agree, the launch is stopped. And these computers are not your ordinary pocket calculators:

Slide Description	Dialogue
	they are so fast in making calculations that they can perform 35,000 operations in one second. For example, the computers on the shuttle can add 2 and 2 35,000 times in one second.
21) Shuttle Columbia main engine start	Three seconds before launch, the computer starts the three main engines on the back of the orbiter. They are started one at a time, only 2/3 of a second apart. (The reason for this is to avoid build-up of pressure due to the firing of the engines.) It takes only 3 seconds for the engines to throttle up to 90% power.
22) Shuttle Columbia launch 23) Shuttle Columbia above clouds during ascent 24) Drawing of SRB separation 25) Drawing of shuttle and external tank before tank separation	At T minus 0 seconds, the SRB's are ignited. Once the SRB's are turned on, there is no turning back; they cannot be turned off. In less than one minute, the shuttle will be travelling faster than the speed of sound - nearly 800 miles per hour. Two minutes after launch, the SRB's are expended and jettisoned. Six minutes later (or 8 minutes after launch), the external tank is empty and likewise jettisoned. Now the shuttle has enough height to be in orbit around the Earth, 100-150 miles up in space.
26) Drawing of shuttle in orbit (earth below) 27) Drawing of shuttle in orbit	Once the astronauts are in orbit, they begin a number of activities and experiments. These activities vary from flight to flight. However a large part of the activities the astronauts perform are exactly the same as many of the everyday tasks we do here on Earth. For instance in each 24 hour period of activity, there is a scheduled 8 hour sleep period. But how do you sleep in space? You cannot go to bed, because there is no bed on the shuttle. There is really no need to lay your head down on a pillow, because it floats in space. If you wanted, you could sleep in space by simply floating in the air and closing your eyes. Remember, being in weightlessness means there is absolutely no pull on your arms, legs, or body. The best way to imagine what weightlessness is like is to float in a swimming pool. Lying on your back in a swimming pool is the closest approach we can

Slide Description	Dialogue
28) Astronaut sleeping vertically	make to feeling the sensation of weightlessness. So on the shuttle all you would have to do is close your eyes and float. However, the astronauts on the shuttle sleep a little differently. To keep themselves from bumping into instruments or slamming into walls while they are alseep, they strap themselves to the sides of the shuttle. Some sleep upright, some sleep horizontally.
29) Astronaut sleeping horizontally	
30) Food package (type of food unknown)	How about eating? How do the astronauts eat in space? Before the space shuttle, astronauts would eat freeze-dried food stored in plastic containers. To rehydrate the food, water was injected into the pack and after kneading the contents the food became a puree and was squeezed through a tube into the astronaut's mouth. If this does not sound too bad, think about this: take a peanut butter and jelly sandwich, put it in a blender and turn it on. Then take the mixture and put it in an oven to take the water out. After putting the dried lump in a plastic bag, take some cold water and mix the contents up. Make a hole in the bag and suck the "delicious" treat out through the hole. This is what is was like to eat in space before the space shuttle.
31) Astronauts at galley (galley pictured in background)	On the shuttle the astronauts have a food galley which features hot and cold water, a pantry which holds the food packs, an oven to heat food, serving trays, a personal hygiene station and a water heater. The biggest improvement is the menu. the current shuttle menu contains over 70 food items and 20 beverages. Astronauts have a varied menu every day for six days, three meals each day which contain such tantalizing tidbits as beef steak, scrambled eggs, shrimp cocktail, stewed tomatoes, broccoli, dried apricots and Life Saver candy.
32) Space Shuttle toilet	And of course, there is one human function that we all must do everyday. Even though the astronauts are in outer space they cannot escape the arduous task of going to the bathroom. Here is a picture of the space toilet aboard the space shuttle which is used by both men and women astronauts.

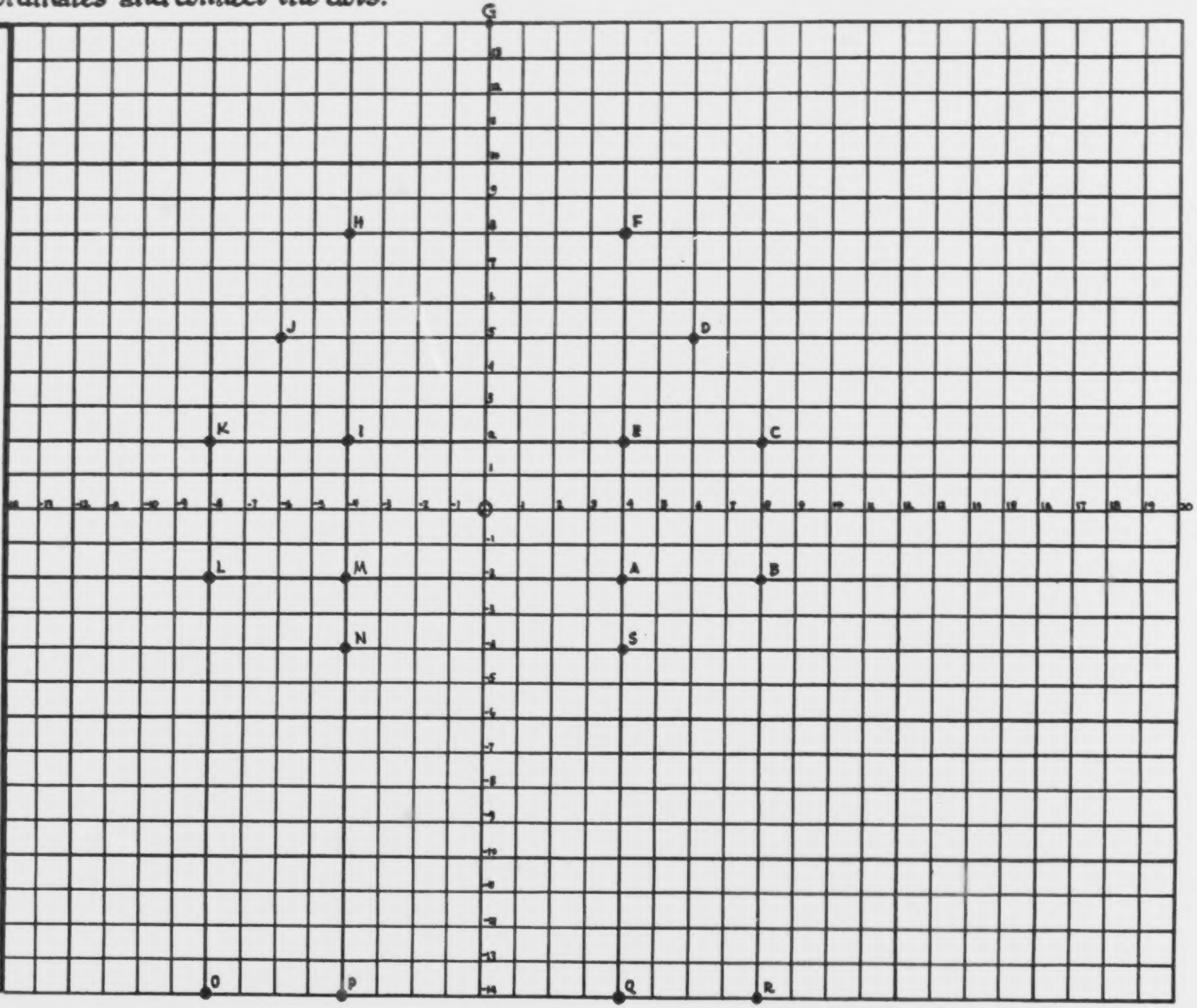
Slide Description	Dialogue
	Teacher Information: The engineering task of designing a toilet for weightlessness is extremely difficult. The toilet operates with a series of pumps, valves and storage tanks. And in the 24 shuttle flights to date it has only operated properly on seven flights. The toilet is built by General Electric and required 12 years of engineering development costing a total of 5 million dollars.
	If you don't think that going to the bathroom in zero gravity is difficult, just remember : in space everything floats.
33) Drawing of shuttle returning from space 34) Drawing of shuttle entering the atmosphere	Once the astronauts conclude their activity in space, they prepare the shuttle to re-enter the atmosphere. In many respects, re-entry is the most important aspect of the mission because of the intense heat caused by friction - the interaction of the air molecules with the shuttle's skin. During re-entry the shuttle experiences temperatures of up to 2600 degrees F (a cake is baked at 350 degrees).
35) White tiles on Columbia being glued into place 36) Black tiles on underside of shuttle	To protect the shuttle from this intense heat, the skin is covered with protective tiles. The tiles, which vary in size but are on the average about 6 cubic inches, absorb the heat into their center, thus protecting the shuttle's aluminum skin.
	Teacher Information: The tiles are made of a very pure and fine silica fiber. They consist of 95% void (or air) and 5 % silica fiber (glass). The first shuttle, Columbia, is covered with 33,000 tiles. The white tiles are for temperatures between 600 and 1200 degrees F. The black tiles are for temperatures between 1200 and 2300 degrees F. The grey area on the nose and leading edge of the wing is reinforced carbon-carbon (similar to the heat shield on the Apollo) which protects the shuttle from temperatures exceeding 2300 degrees.
37) Shuttle as it enters the atmosphere	As you remember, the shuttle jettisoned its rockets when it reached orbit, leaving it without power (There are little thrusters that are used in orbit to maneuver the shuttle). Therefore when the shuttle returns to Earth, it is a glider - an airplane without engine power.

Slide Description	Dialogue
38) Shuttle on 25 degree glide slope (small plane in picture is a "chase plane")	Once the shuttle enters the atmosphere it is travelling nearly 25 times the speed of sound (over 17,000 miles per hour). Most airplanes when they come in for a landing, make a rate of descent less than 2 degrees to the horizon. The shuttle is literally falling at a slope of 25 degrees.
39) Shuttle deploying landing gear	To slow itself down, the shuttle makes a series of "S" turns like a skier descending a mountain slope. On final approach to its landing site, the shuttle lowers its landing gear at about 200 feet above the ground and lands at an approximate speed of 220 miles per hour.
40) Shuttle landing in California	
41) Shuttle piggy-back on 747	After the shuttle has landed, it is taken back to Florida on the back of a 747, where it will be readied for another flight.
42) Shuttle launch	

Record Sheet: ALL ABOARD COORDINATE PUZZLE **Name** ______________________

Name the coordinates and connect the dots.

A	(4 ,-2)
B	(8 ,-2)
C	(8,2)
D	(6 ,5)
E	(4 ,2)
F	(4 ,8)
G	(0 ,14)
H	(-4 ,8)
I	(-4,2)
J	(-6,5)
K	(-8,2)
L	(-8,-2)
M	(-4,-2)
N	(-4,-4)
O	(-8,-14)
P	(-4 ,-14)
Q	(4 ,14)
R	(8 ,-14)
S	(4 ,-4)



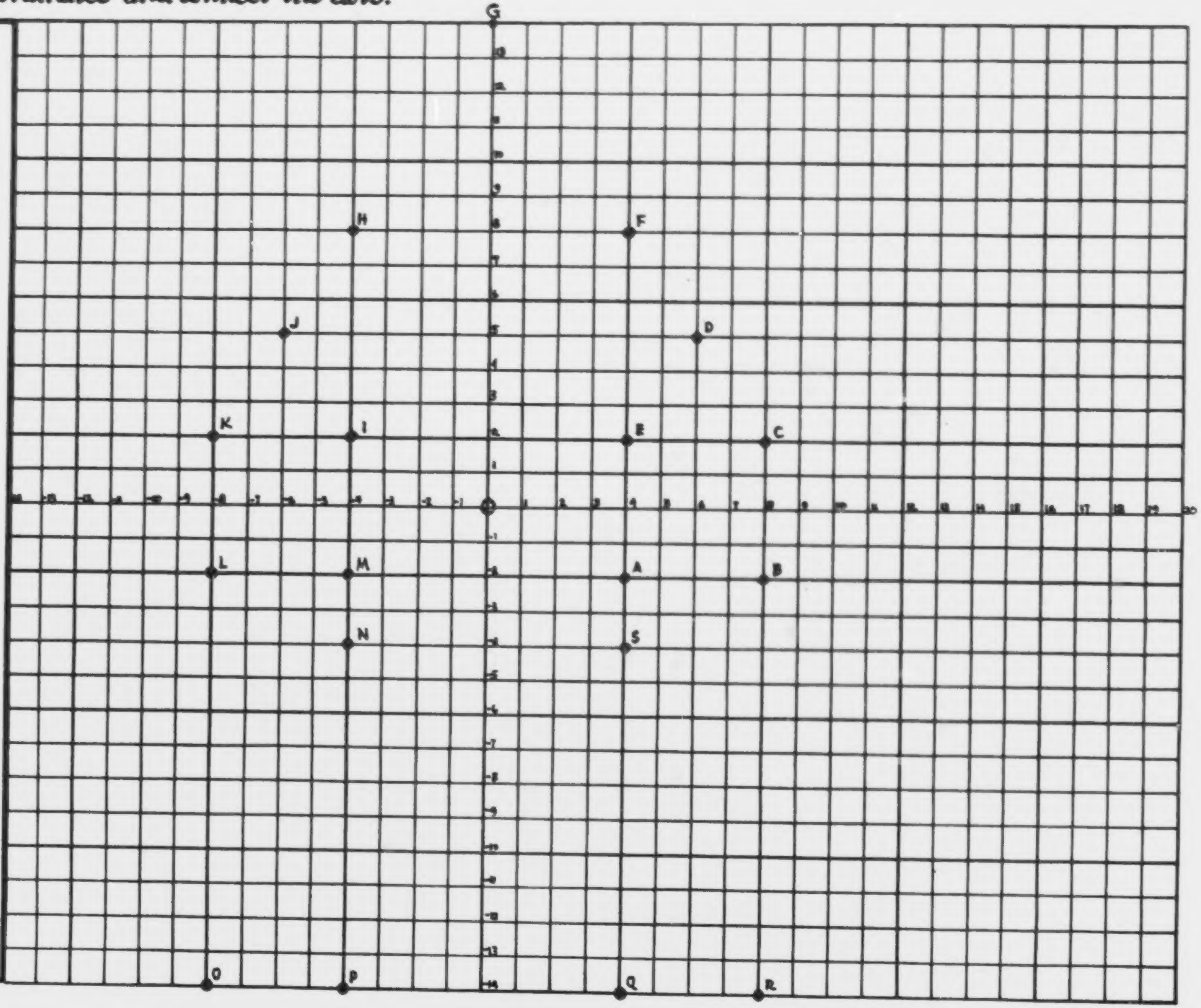
Regional Math Network • Harvard Graduate School of Education • Harvard University

Record Sheet: ALL ABOARD COORDINATE PUZZLE

Name ______________________________

Name the coordinates and connect the dots.

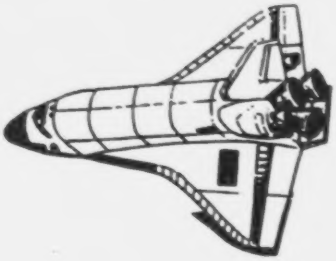
A (,)
B (,)
C (,)
D (,)
E (,)
F (,)
G (,)
H (,)
I (,)
J (,)
K (,)
L (,)
M (,)
N (,)
O (,)
P (,)
Q (,)
R (,)
S (,)



Regional Math Network • Harvard Graduate School of Education • Harvard University

THE SHUTTLE... LET'S MAKE IT

Preparation/Materials	**Math Skills**
- Make a model of the orbiter before class to become aware of its idiosyncrasies. - Make an overhead of the Orbiter Blueprint, (Optional) - "Orbiter Blueprint" - Scissors for each student - Rubber cement (not glue)	- Plane Figures - Scale Models and Scale Drawing - Estimation in Computation - Logical Problem Solving



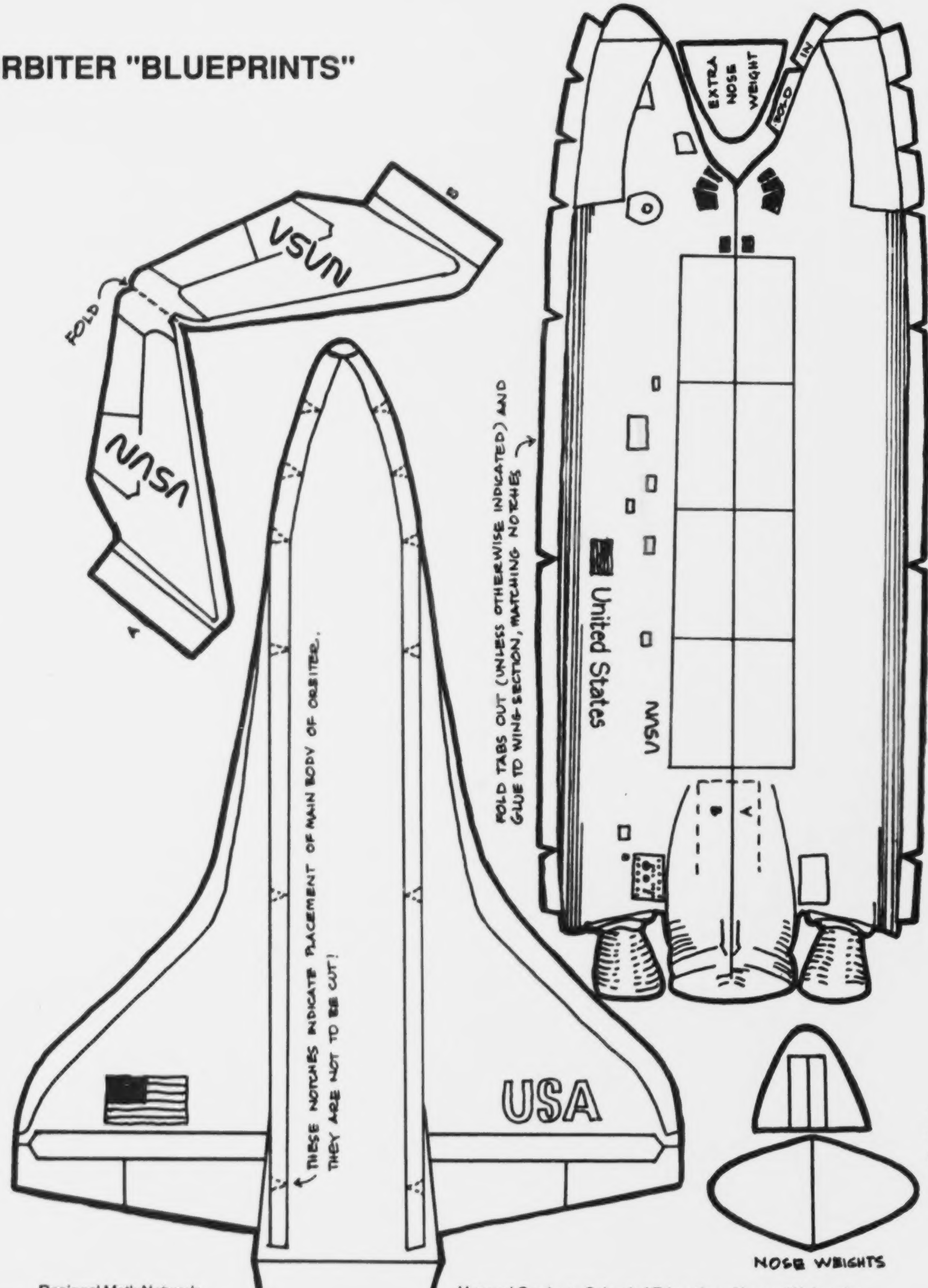
During class:

- Help the students make their models of the orbiter using the orbiter blueprint plans. Making a model helps students gain familiarity with the orbiter, its components and its proportionality. The students' models for the orbiter will be used in later activities.

- Discuss:
  - the design of the orbiter;
  - the shapes suggested by its various parts, i.e., wings look like triangles, the body looks like half of a cylinder, its engines look like truncated cones...

Extensions
- "The Shuttle"
- Fly the orbiters in competition; mark and measure the landing points. The orbiter who flies the farthest wins!
- "Creative Blast-Off"

ORBITER "BLUEPRINTS"


FOLD
NASA
NASA
A
B
THESE NOTCHES INDICATE PLACEMENT OF MAIN BODY OF ORBITER.
THEY ARE NOT TO BE CUT!
USA
FOLD TABS OUT (UNLESS OTHERWISE INDICATED) AND GLUE TO WING SECTION, MATCHING NOTCHES
EXTRA NOSE WEIGHT
FOLD
IN
United States
NASA
A
B
NOSE WEIGHTS

Name________________

THE SHUTTLE

Payload is the term used to describe the cargo that the shuttle can carry into or bring out of space.

The total weight of the shuttle at lift-off is 4,457,825 lbs.
Each of the two rocket boosters weighs 193,000 lbs. and carries about .55 million lbs. of fuel.
The external tank weighs 76,000 lbs. and carries 1.66 million lbs. of fuel.
The orbiter without payload weighs 150,000 lbs.

1. Two minutes after launch, the fuel in the booster rockets is exhausted and the rockets are jettisoned.

   What is the approximate weight loss?

   ≈ 1,500,000 lbs.

2. After 8 minutes, the fuel from the external tank is exhausted and the tank is jettisoned.

   How much of the original weight at launch remains?

   ≈ 1,200,000 lbs.

3. In terms of weight, how much cargo can be carried on the shuttle?

   ≈ 1,080,000 lbs.

Name________________

THE SHUTTLE

4. If the solid booster separation occurs at 131.7 seconds into flight at an altitude of 165,605 feet and orbital operations begin 2717.4 seconds into flight at an altitude of approximately 100 miles, what is the approximate difference in altitude from solid booster separation to orbit operations?

   ≈ 362,000 ft.

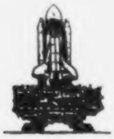
5. The shuttle Columbia travels at 17,500 m.p.h. while in orbital operations. The length of the shuttle's orbit is 26,500 miles.

   Approximately how many orbits does the shuttle travel in one day?

   15.8 or ≈ 16 orbits

6. About how many days was Columbia in orbit if it travelled 1,428,000 miles?

   ≈ 3.5 days



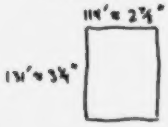
Name________________

THE SHUTTLE

7. The mobile launching pad is carried by an eight-tracked crawler transporter, by far the world's biggest land vehicle.

   The platform measures 131' by 114'

   Draw a scale drawing of the platform. Scale 1" = 40'



   What is the approximate area of the mobile launching pad?

   area ≈ 131' × 114' ≈ 15,000 sq. ft.

8. The crawler brings the shuttle from the Vehicle Assembly Building to the launch pad. The journey will take between 5 and 6 hours.

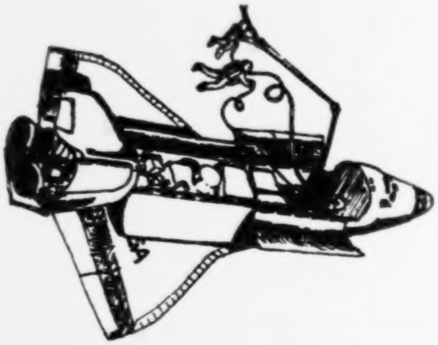
   The launch pad is only 3.5 miles away from the Vehicle Assembly Building.

   How fast is the crawler travelling?

   between .6 and .7 M.P.H.

Name________________________

THE SHUTTLE



Payload is the term used to describe the cargo that the shuttle can carry into or bring out of space.

The total weight of the shuttle at lift-off is 4,457,825 lbs.
Each of the two rocket boosters weighs 193,000 lbs. and carries about .55 million lbs. of fuel.
The external tank weighs 78,000 lbs. and carries 1.66 million lbs. of fuel.
The orbiter without payload weighs 150,000 lbs.

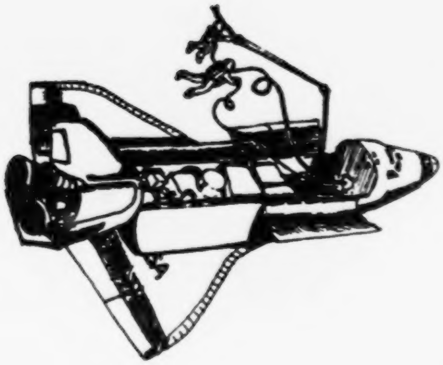
1. Two minutes after launch, the fuel in the booster rockets is exhausted and the rockets are jettisoned.

   What is the approximate weight loss?

2. After 8 minutes, the fuel from the external tank is exhausted and this tank is jettisoned.

   How much of the original weight at launch remains?

3. In terms of weight, how much cargo can be carried on the shuttle?



Name ____________________

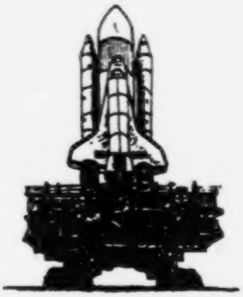
THE SHUTTLE

4. If the solid booster separation occurs at 131.7 seconds into flight at an altitude of 165,605 feet and orbital operations begin 2717.4 seconds into flight at an altitude of approximately 100 miles, what is the approximate difference in altitude from solid booster separation to orbit operations?

5. The shuttle Columbia travels at 17,500 m.p.h. while in orbital operations. The length of the shuttle's orbit is 26,500 miles.

   Approximately how many orbits does the shuttle travel in one day?

6. About how many days was Columbia in orbit if it travelled 1,428,000 miles?



Name ______________________

THE SHUTTLE

7. The mobile launching pad is carried by an eight-tracked crawler transporter, by far the world's biggest land vehicle.

   The platform measures 131' by 114'

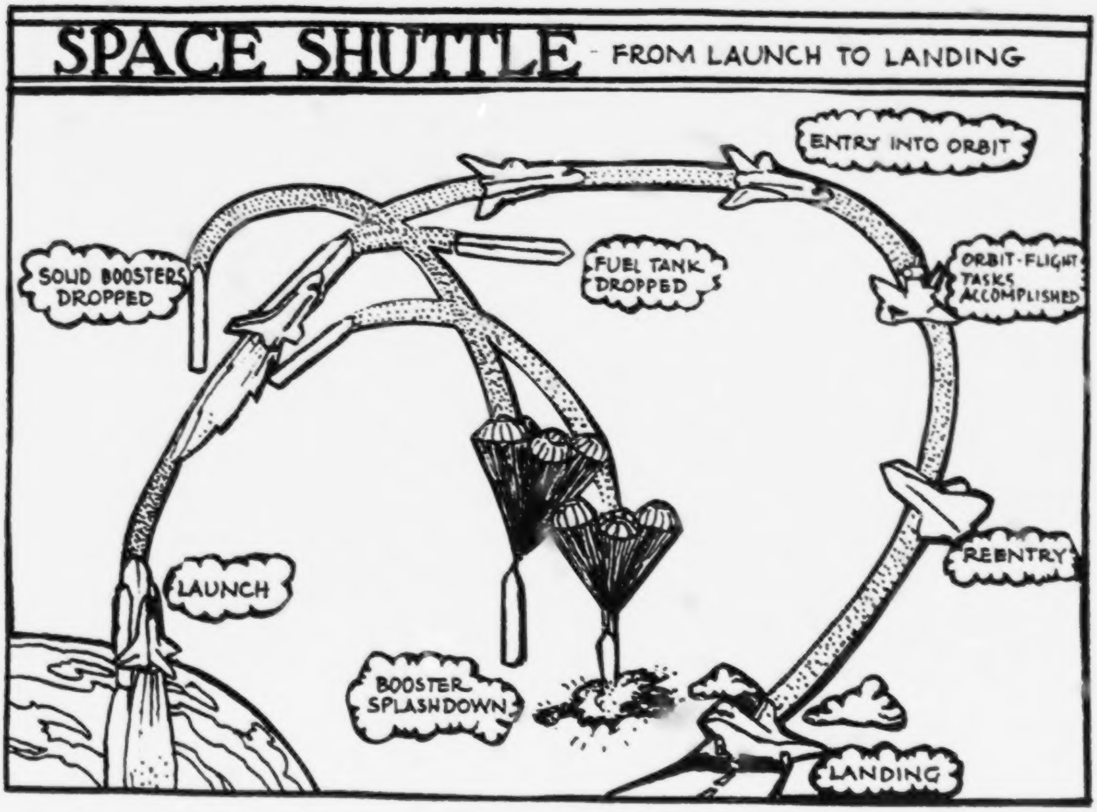
   Draw a scale drawing of the platform. Scale 1" = 40'

   What is the approximate area of the mobile launching pad?

8. The crawler brings the shuttle from the Vehicle Assembly Building to the launch pad. The journey will take between 5 and 6 hours.

   The launch pad is only 3.5 miles away from the Vehicle Assembly Building.

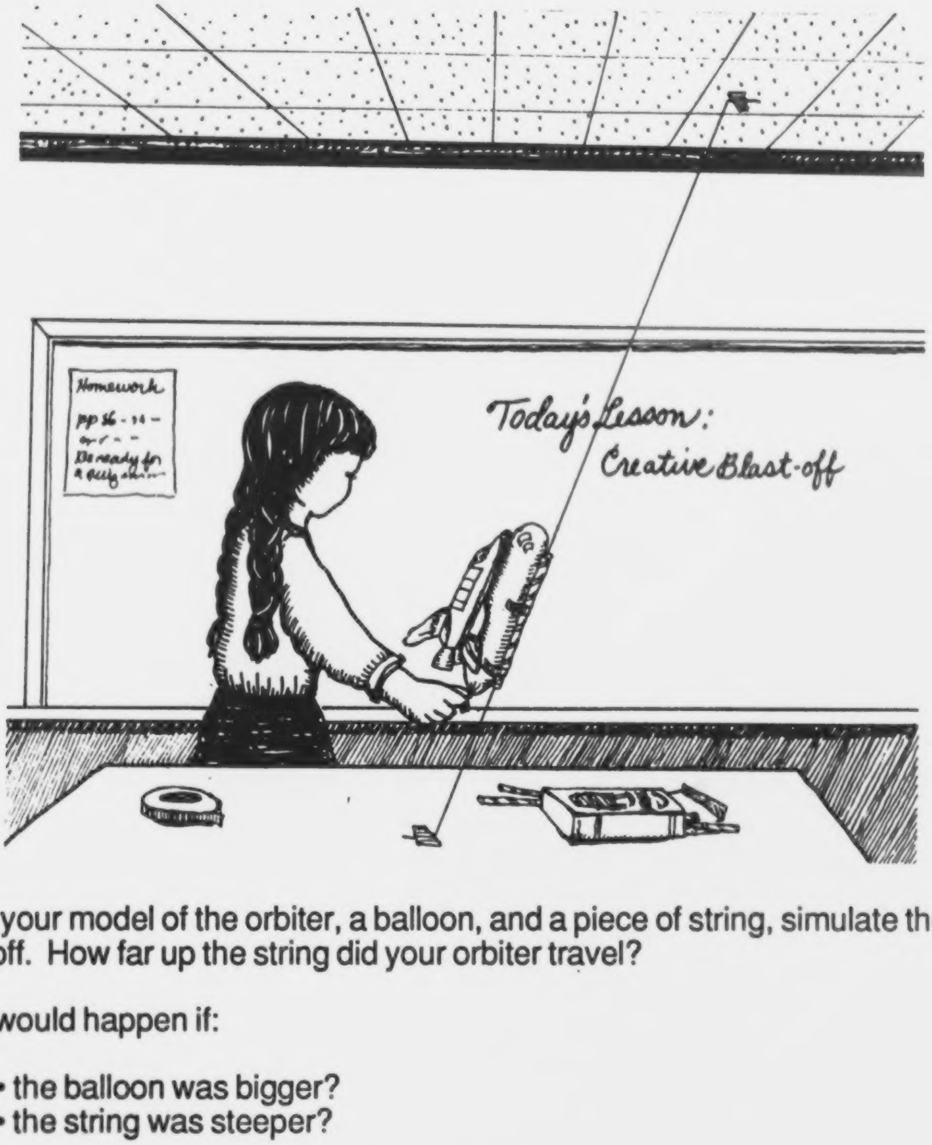
   How fast is the crawler travelling?


SPACE SHUTTLE - FROM LAUNCH TO LANDING
ENTRY INTO ORBIT
SOLID BOOSTERS DROPPED
FUEL TANK DROPPED
ORBIT-FLIGHT TASKS ACCOMPLISHED
LAUNCH
REENTRY
BOOSTER SPLASHDOWN
LANDING

Poster

Name ____________________

CREATIVE BLAST-OFF



Using your model of the orbiter, a balloon, and a piece of string, simulate the blast-off. How far up the string did your orbiter travel?

What would happen if:

- the balloon was bigger?
- the string was steeper?

How could you make the orbiter travel faster?

ORBITER
"SPECS"

Preparation/Materials	**Math Skills**
• "Orbiter Specs" • Orbiter Model • Ruler	• Scale and Scale Drawing

During class:

- Introduce the class to the various parts of the orbiter using a scale model. Point out the different orbiter features and their uses:
  - Wings and wing span
  - Body: Its width and height
  - Payload bay
  - Mid deck
  - Flight deck
  - "Decals": the flag and the USA

- Explain to the students that the dimensions of this scale model are proportional to the dimensions of the actual orbiter.

- Pose the question:
  "If we know that the wing span of the model represents an actual wing span of 78 feet, what would be the length of the actual orbiter?"

- Teach the students how to use their scale model of the orbiter along with ratio and proportion techniques to determine other measurements of the orbiter.

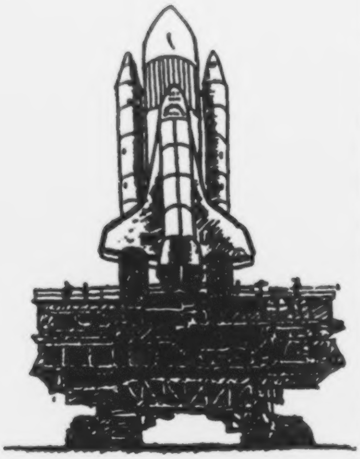
Extensions

- "The Shuttle System: How Big Is It?"
- Ask students to pick an object in their house and make a model of it, using the same scale as used in the orbiter model.

Name ______________________

ORBITER "SPECS"

Use your model of the orbiter to find:

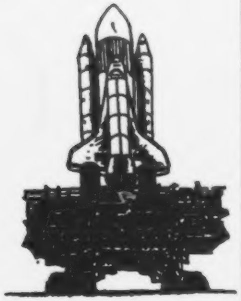


	Measure on scale model	Estimate of actual measure
Wing Span		78 feet
Length		
Height of Payload Bay		
Length of Payload Bay		
Height of "U" in "United States" decal		
Height of "N" in "NASA"		
Height of Flag		
Width of Flag		

Name ____________________

ORBITER "SPECS"

Use your model of the orbiter to find:

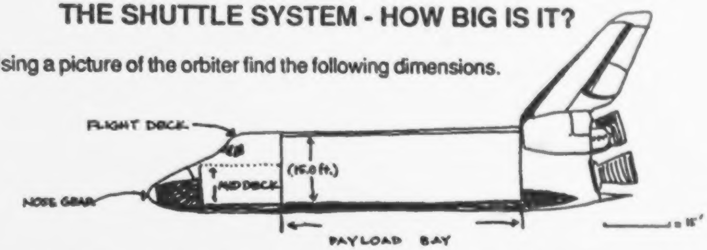


	Measure on scale model	Estimate of actual measure
Wing Span	≈ 5.25"	78 feet
Length	≈ 7.75"	115'
Height of Payload Bay	≈ 1"	15'
Length of Payload Bay	≈ 4"	59'
Height of "U" in "United States" decal	≈ 1/4"	3.7'
Height of "N" in "NASA"	≈ 3/16"	2.8'
Height of Flag	≈ 3/8"	5.6'
Width of Flag	≈ 5/8"	9.4'

Name ____________________

THE SHUTTLE SYSTEM - HOW BIG IS IT?

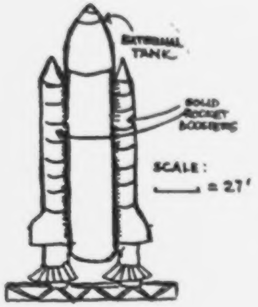
1. Using a picture of the orbiter find the following dimensions.



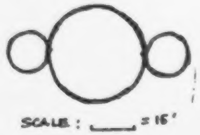
- About how long is the payload bay? 3.5 x 15' = 52.5'
- About how long is the middeck? 15'
- About how high is the middeck? 8'
- What is the total area astronauts have available in which to live and work? 8' x 15' = 120 sq. ft.

2. Looking at the two views of the external tank and solid rocket boosters:

From the back:



From the bottom:
The engines:

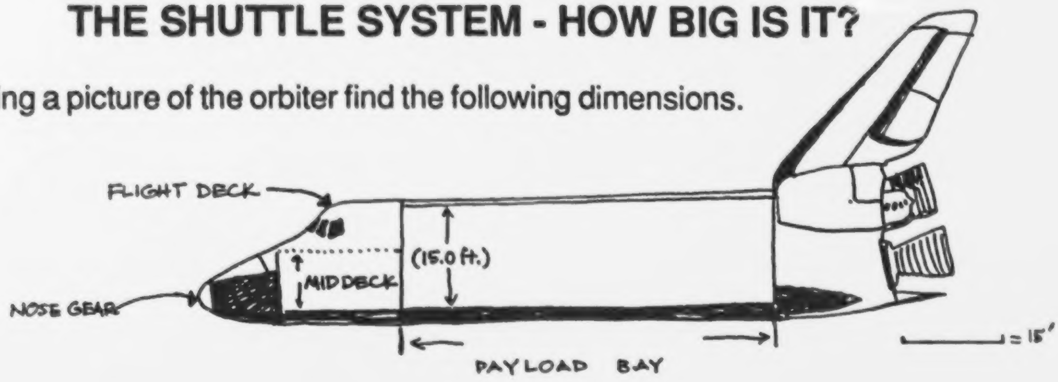


Estimate the Dimensions:	Solid Rocket Booster	External Tank
Length	27' x 6 = 162	27' x 7 = 189'
Diameter	13'	30'

Name ____________________

THE SHUTTLE SYSTEM - HOW BIG IS IT?

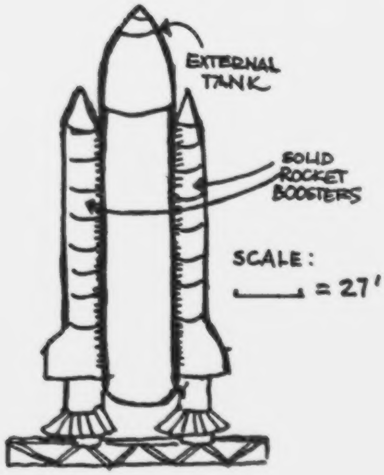
1. Using a picture of the orbiter find the following dimensions.



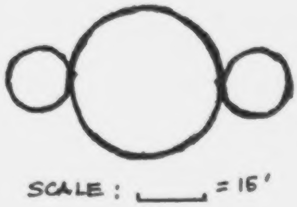
- About how long is the payload bay? ____________________
- About how long is the middeck? ____________________
- About how high is the middeck? ____________________
- What is the total area astronauts have available in which to live and work? ____________________

2. Looking at the two views of the external tank and solid rocket boosters:

From the back:



From the bottom:
The engines:



Estimate the Dimensions:	Solid Rocket Booster	External Tank
Length		
Diameter		

SURE IT'S BIG...
...BUT COMPARED TO WHAT?

Preparations/Materials	**Math Skills**
• Prepare Measurement Trivia Sheet for student use (Fact Book) • "More Comparisons"	• Estimation in Computation • Ratio and Proportion

During class:

- Distribute and discuss the Measurement Trivia Sheet.
  It lists familiar measurements which may have meaning for students.
- Work together with the class to compare the length of the shuttle with the length of an MBTA bus. Use a ratio to compare the lengths.

$$\frac{\text{Length of Orbiter}}{\text{Length of Bus}} = \frac{122\text{ ft.}}{40\text{ ft.}}$$

The orbiter is about 3 times longer.

- Discuss with students that we should compare the orbiter to things we know in order to appreciate its size and power.
- Ask the students to use ratios to find the solutions to "More Compaisons."

Extensions
- "Sure It's Big, But Compared to What?"
- Ask students to find more measurement trivia and to use these facts to make comparisons with characteristics of the orbiter.

Name ______________________

MORE COMPARISONS...

1. The orbiter travels at approximately 17,500 m.p.h. when in orbit.
   - How much faster is the orbiter than a jet?

     Ratio:

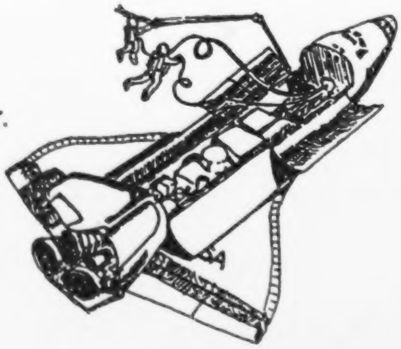
     The orbiter is about __________ times faster than a jet.
   - How much faster is the orbiter than a car?

     Ratio:

     The orbiter is about __________ times faster than a car.
   - How much faster is the speed of light than the orbiter?

     Ratio:

     The speed of light is about __________ times faster.



2. The cargo bay can hold about 65,000 lbs.
   - Approximately how many elephants could be transported in the cargo bay?
   - About how many MBTA buses could be transported in the cargo bay?
   - About how many Refrigerator Perrys, packed together like sardines, could be transported in the cargo bay?
3. The orbiter is subjected to a temperature of 2700 degrees Fahrenheit during re-entry.
   - About how much hotter is this than the temperature of boiling water? (Water boils at 212° F) ______________
   - About how much hotter is this than the Earth's maximum temperature?

     ____
4. The shuttle's "nervous system" consists of five computers. Each computer has a memory bank of 48,261 words.
   - To the nearest thousand, how many words can be stored? ________________

Name ____________________

MORE COMPARISONS...

1. The orbiter travels at approximately 17,500 m.p.h. when in orbit.

- How much faster is the orbiter than a jet?

  Ratio: $\frac{17,500}{650}$

  The orbiter is about 27 times faster than a jet.

- How much faster is the orbiter than a car?

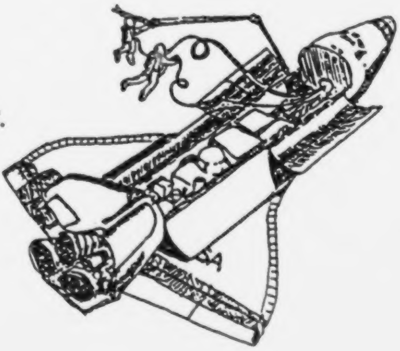
  Ratio: $\frac{17,500}{55}$

  The orbiter is about 318 times faster than a car.

- How much faster is the speed of light than the orbiter?

  Ratio: $\frac{186,000 \text{ m.p.s}}{4.9 \text{ m.p.s}}$

  The speed of light is about 38,000 times faster.



2. The cargo bay can hold about 65,000 lbs.

- Approximately how many elephants could be transported in the cargo bay?

  8 elephants

- About how many MBTA buses could be transported in the cargo bay?

  2 buses

- About how many Refrigerator Perrys, packed together like sardines, could be transported in the cargo bay? 210 Perrys

3. The orbiter is subjected to a temperature of 2700 degrees Fahrenheit during re-entry.

- About how much hotter is this than the temperature of boiling water? (Water boils at 212° F) 13 times

- About how much hotter is this than the Earth's maximum temperature? 20 times

4. The shuttle's "nervous system" consists of five computers. Each computer has a memory bank of 48,261 words.

- To the nearest thousand, how many words can be stored? 241,000 words

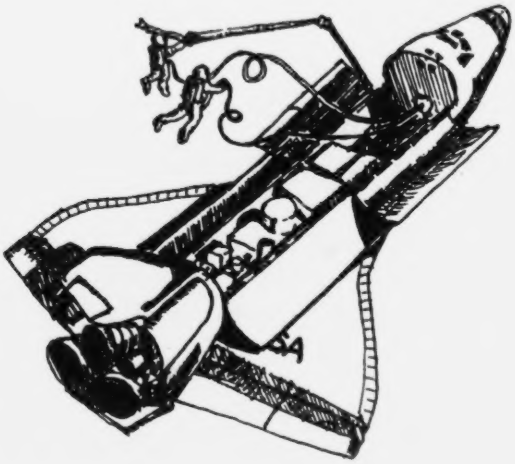
Name ______________________

ORBITER:

Actual length of Orbiter = 122'
Actual length of MBTA Bus = 40'
The Orbiter is about 4 times longer.

SURE IT'S BIG..

Choose something you know to compare
to the Orbiter
Actual length of Orbiter = ______________
Compared to: ______________________
The __________is about_____times longer.



Actual height of the Orbiter = ___________
Compared to: ______________________
The ________________________is about
_______________________ times higher.

Actual weight of the Orbiter = ___________
Compared to: ____________________
The________________________is about
______________________ times heavier.

Maximum speed of Orbiter = ___________
Compared to: ______________________
The _______________________is about
________________________times faster.

Actual Width (Wing span of Orbiter) = _____
Compared to: ______________________
The wing span is
________________________times wider.

PAYLOAD ARM:

Actual length of payload arm =_________
Compared to:_______________________
The________________________is about
________________________times longer.

BUT COMPARED TO WHAT?

EXTERNAL TANK:

Weight at take-off =____________________
Compared to:_______________________
The tank is
________________________times heavier.

PLANNING FOR LIFE ON BOARD...
...LET'S EAT

Preparation/Materials	**Math Skills**
• "Space Shuttle Food and Beverage List" • "Let's Eat" • Calculator (Optional)	• Estimation in Computation • Logical Problem Solving

During class:

- Discuss types of planning that must go on in order for astronauts to live in the orbiter during the mission.
- Consider the problem of meal planning.
  - Why must the food be prepackaged?
  - Why must the food be easily cooked?
  - Why must the food be compact?
  - Why must the food be as light in weight as possible?
- Explain to the students that each astronaut must consume 2500 calories a day.
- Ask the students to estimate the amount of each kind of food allowed for a given menu, so that an astronaut does not exceed the required number of total calories.
- Discuss what other elements of daily life must be preplanned:
  - showers
  - exercise
  - going to the bathroom!
  - other?

Extensions

- "Crew's Quarters"
- Make acceptable substitutions on menu, total calories must remain the same.
- Plan another day's menu.

Name ____________________________

LET'S EAT!

Typical Menu for the First Four Shuttle Flights

DAY 1	DAY 2	DAY 3	DAY 4
Peaches Beef patty Scrambled eggs Bran flakes Cocoa Orange drink	Applesauce Beef jerky Granola Breakfast roll Chocolate instant breakfast Orange-grapefruit drink	Dried peaches Sausage Scrambled eggs Cornflakes Cocoa Orange-pineapple drink	Dried apricots Breakfast roll Granola w/ blueberries Vanilla instant breakfast Grapefruit drink
Frankfurters 50 ea.* Turkey tetrazzini 340 Bread 56 * Bananas 100 ea. * Almond crunch bar 210 * Apple drink 116 *	Corned beef 422 * Asparagus 44/cup * Bread 56 * Pears Peanuts Lemonade	Ham Cheese spread Bread Green beans and broccoli Crushed pineapple Shortbread cookies Cashews Tea w/lemon and sugar	Ground beef w/ pickle sauce Noodles and chicken Stewed tomatoes Pears Almonds Strawberry drink
Shrimp cocktail Beef steak Rice pilaf Broccoli au gratin Fruit cocktail Butterscotch pudding Grape drink	Beef w/barbecue sauce 500 * Cauliflower w/cheese 700 * Green beans w/ mushrooms 54/c. * Lemon pudding Pecan cookies Cocoa	Cream of mushroom soup Smoked turkey Mixed Italian vegetables Vanilla pudding Strawberries Tropical punch	Tuna Macaroni and cheese Peas w/butter sauce Peach ambrosia Chocolate pudding Lemonade

* indicates calorie count.

ASTRONAUTS MUST EAT A CAREFULLY PLANNED DIET OF 2500 CALORIES PER ASTRONAUT PER DAY.

TYPICAL MENUS ARE ABOVE. THEY TELL YOU WHAT THE ASTRONAUTS EAT, BUT NOT ALWAYS HOW MUCH.

1. The lunch menu for Day 1 used up 1022 calories.
   All food amounts are indicated, except for the frankfurters and bananas.
   How much of each could an astronaut have eaten and stayed within the calorie count?

2. Look at dinner on Day 2. How much lemon pudding, pecan cookies and cocoa was allowed?
   Dinner = 1421 calories.

3. If you were to make 3 substitutions on Day 3, what would they be? Remember total calories must remain the same.

4. Plan a menu for Day 5. Do your work on the back of this page.

Name ____________________

LET'S EAT!

Typical Menu for the First Four Shuttle Flights

DAY 1	DAY 2	DAY 3	DAY 4
Peaches Beef patty Scrambled eggs Bran flakes Cocoa Orange drink	Applesauce Beef jerky Granola Breakfast roll Chocolate instant breakfast Orange-grapefruit drink	Dried peaches Sausage Scrambled eggs Cornflakes Cocoa Orange-pineapple drink	Dried apricots Breakfast roll Granola w/ blueberries Vanilla instant breakfast Grapefruit drink
Frankfurters 50 ea.* Turkey tetrazzini 340 Bread 56 * Bananas 100 ea. * Almond crunch bar 210 * Apple drink 116 *	Corned beef 422 * Asparagus 44/cup * Bread 56 * Pears Peanuts Lemonade	Ham Cheese spread Bread Green beans and broccoli Crushed pineapple Shortbread cookies Cashews Tea w/lemon and sugar	Ground beef w/ pickle sauce Noodles and chicken Stewed tomatoes Pears Almonds Strawberry drink
Shrimp cocktail Beef steak Rice pilaf Broccoli au gratin Fruit cocktail Butterscotch pudding Grape drink	Beef w/barbecue sauce 500 * Cauliflower w/cheese 700 * Green beans w/ mushrooms 54/c. * Lemon pudding Pecan cookies Cocoa	Cream of mushroom soup Smoked turkey Mixed Italian vegetables Vanilla pudding Strawberries Tropical punch	Tuna Macaroni and cheese Peas w/butter sauce Peach ambrosia Chocolate pudding Lemonade

* indicates calorie count.

ASTRONAUTS MUST EAT A CAREFULLY PLANNED DIET OF 2500 CALORIES PER ASTRONAUT PER DAY.

**TYPICAL MENUS ARE ABOVE.
THEY TELL YOU WHAT THE ASTRONAUTS EAT, BUT NOT ALWAYS HOW MUCH.**

1. The lunch menu for Day 1 used up 1022 calories.
All food amounts are indicated, except for the frankfurters and bananas.
How much of each could an astronaut have eaten and stayed within the calorie count?

	Possible Combinations			
Frankfurters	6	4	2	0
Bananas	0	1	2	3

2. Look at dinner on Day 2. How much lemon pudding, pecan cookies and cocoa was allowed?
Dinner = 1421 calories.

167 calories left for lemon pudding, pecan cookies and cocoa

3. If you were to make 3 substitutions on Day 3, what would they be? Remember total calories must remain the same.

4. Plan a menu for Day 5. Do your work on the back of this page.

Space Shuttle Food and Beverage List

Foods*

AppleSauce (T) 100/cup
Apricots, dried (IM) 332/cup
Asparagus (R) 44/cup
Bananas (FD) 135/cup
Beef almondine (R) 272/4oz.
Beef, corned (I) (T) 422/4oz.
Beef and gravy (T) 272/4oz.
Beef, ground, w/pickle sauce(T)272
Beef jerky (IM) 272/4oz.
Beef patty (R) 303/4oz.
Beef, slices w/barbeque sauce (T) 500/4oz.
Beef steak (T) 272/4oz.
Beef stroganoff w/noodles 500/4oz.
Bread, seedless rye (NF) 56/slice
Broccoli au gratin (R)100/cup
Breakfast roll (NF) 90/each
Candy, Life Savers, assorted flavors (NF) 25/each
Cauliflower w/cheese (R) 78/cup
Cereal, bran flakes (R) 106/cup
Cereal, cornflakes (R) 97/cup
Cereal, granola (R) 130/cup
Cereal, granola w/blueberries(R)175
Cereal, granola w/raisins (R) 241
Cheddar cheese spread (T) 450/cup
Chicken a la king (T) 468/cup
Chicken and noodles (R) 658/cup
Chicken and rice (R) 658/cup
Chili mac w/beef (R) 302/cup
Cookies, pecan (NF) 100/each
Cookies, shortbread (NF) 141/each
Crackers, graham (NF) 62/each
Eggs, scrambled (R) 123/ea.
Food bar, almond crunch (NF) 150
Food bar, chocolate chip (NF) 150
Food bar, granola (NF) 150
Food bar, granola/raisin (NF) 150
Food bar, peanut butter/granola (NF) 150
Frankfurters (T) 106/ea.
Fruitcake (NF) 379/3oz.
Fruit cocktail (T) 84/cup
Green beans, french w/mushrooms 54/cup
Green beans and broccoli 54/cup
Ham (I) (T) 531/8oz.
Jam/Jelly (T) 78/oz..
Macaroni and cheese (R) 430/cup
Meatballs w/barbeque sauce
Nuts, almonds (NF) 678/4oz.
Nuts, cashews (NF) 639/4oz.
Nuts, peanuts (NF) 660/4oz.
Peach ambrosia (R) 200/cup
Peaches, dried (IM) 419/cup
Peaches (T) 200/cup
Peanut butter 685/4oz.
Pears (FD) 173/ea.
Pears (T) 194/ea.
Peas w/butter sauce (R) 260/cup
Pineapple, crushed (T) 66/cup
Pudding, butterscotch (T) 457/cup
Pudding, chocolate (R) (T) 385/cup
Pudding, lemmon (T) 322/cup
Pudding, vanilla (R) (T) 283/cup
Rice pilaf 223/cup
Salmon (T) 232/4oz.
Sausage patty 129/each
Shrimp cocktail 103/4oz.
Soup, cream of mushroom134/cup
Spaghetti w/meatless sauce(R) 332/cup
Strawberries (R) 55/cup
Tomatoes, stewed (T) 51/cup
Tuna (T) 126/cup
Turkey and gravy (T) 240/4oz.
Turkey, smoked/sliced (I) (T) 240/4oz.
Turkey tetrazzini (R) 340/4oz.
Vegetables, mixed italian (R) 80/cup

Beverages

Apple drink 116/cup
Cocoa 125/cup
Coffee, black 0
Coffee w/cream 45/cup
Coffee w/cream and sugar 95/cup
Coffee w/sugar 45/cup
Grape drink 135/cup
Grapefruit drink 135/cup
Instant breakfast, chocolate 290
Instant breakfast, strawberry 290
Instant breakfast, vanilla 290
Lemonade 107/cup
Orange drink 125/cup
Orange-grapefruit drink 125/cup
Orange-pineapple drink 125/cup
Strawberry drink 125/cup
Tea 0
Tea w/lemon and sugar 45/cup
Tea w/sugar 45/cup
Tropical punch 200/cup

Condiments

Barbeque sauce 228/cup
Catsup 289/cup
Mustard 228/cup
Pepper 0
Salt 0
Hot pepper sauce 0
Mayonnaise 1580/cup

* abbreviations in parantheses indicate type of food T = thermostabilized, I = irradiated, IM = intermediate moisture, FD = freeze dried, R = rehydratable, and NF = natural form

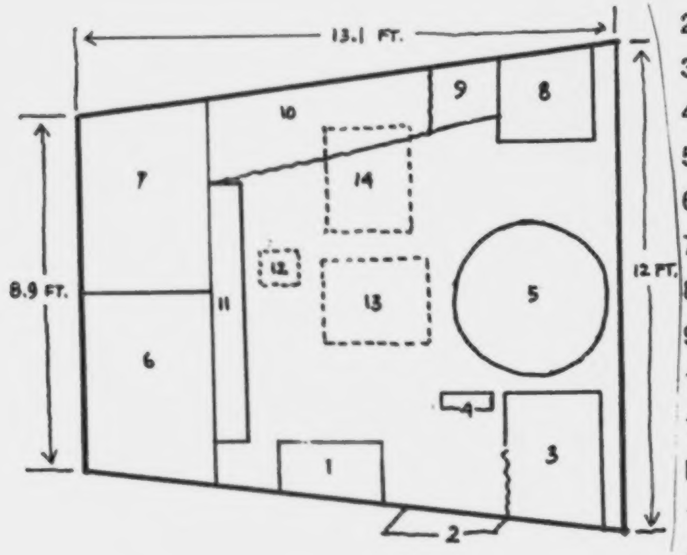
Space Shuttle Menu Design

The Shuttle Menu is designed to provide nutrition and energy requirements essential for good health and effective performance with safe, highly acceptable foods. In order to maintain food nutrition, the menu will provide at least the following quantities of each nutrient each day:

Protein	(g)	56	Vitamin B_{12}	(g)	3.0
Vitamin A	(iu)	5000	Calcium	(mg)	800
Vitamin D	(iu)	400	Phosphorus	(mg)	800
Vitamin E	(iu)	15	Iodine	(µg)	130
Ascorbic Acid	(mg)	45	Iron	(mg)	18
Floacin	(µg)	400	Magnesium	(mg)	350
Niacin	(mg)	18	Zinc	(mg)	15
Riboflavin	(mg)	1.6	Potassium	(meq)	70
Thiamine	(mg)	1.4	Sodium	(meq)	150
Vitamin B_6	(mg)	2.0			

CREW'S QUARTERS

Name________________________

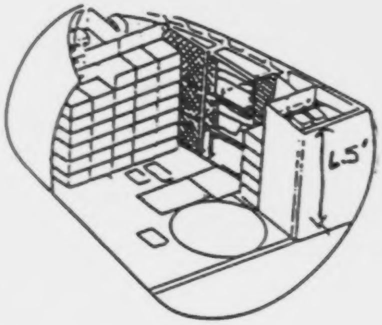


1. Galley
2. Hatch
3. Toilet
4. Ladder to flight deck
5. Airlock
6. Avionics bay 1
7. Avionics bay 2
8. Avionics bay 3
9. Lockers
10. Sleep Station
11. Wall of Lockers

FLOOR HATCHES:

12. Lithium hydroxide changeout
13. Lithium hydroxide storage
14. Wet trash storage

MIDDECK FLOOR PLAN

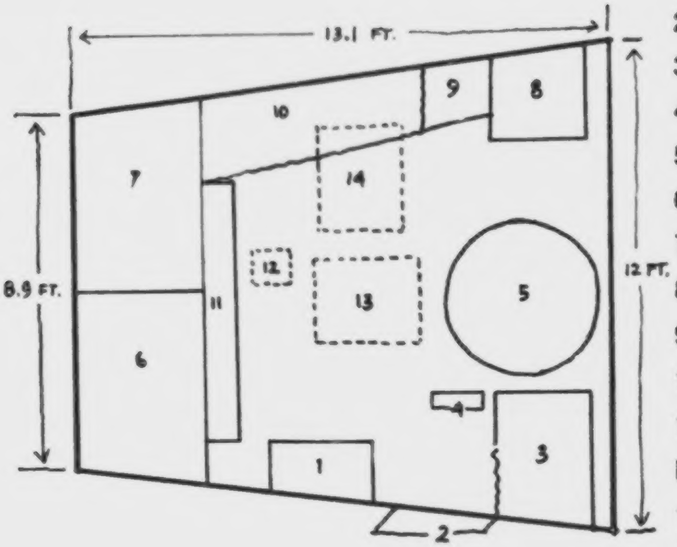


Estimate the size of each.
Find an area in the classroom of the same area.

	Approximate Size	Like a:
Galley	1.5' x 3'	
Toilet	2.5' x 3.5'	
Lockers	1.5' x 1.5'	
Total Floor Space	≈ 117 sq. ft.	

CREW'S QUARTERS

Name________________________

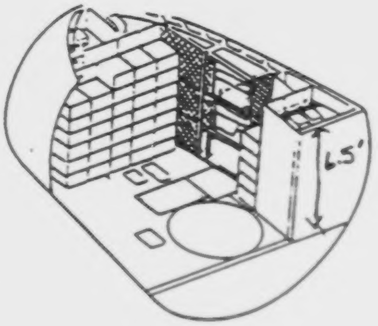


1. Galley
2. Hatch
3. Toilet
4. Ladder to flight deck
5. Airlock
6. Avionics bay 1
7. Avionics bay 2
8. Avionics bay 3
9. Lockers
10. Sleep Station
11. Wall of Lockers

FLOOR HATCHES:

12. Lithium hydroxide changeout
13. Lithium hydroxide storage
14. Wet trash storage

MIDDECK FLOOR PLAN



Estimate the size of each.
Find an area in the classroom of the same area.

	Approximate Size	Like a:
Galley		
Toilet		
Lockers		
Total Floor Space		

PLANNING FOR LIFE ON BOARD...
...LET'S WORK

Preparation/Materials	**Math Skills**
• Build a tetrahedron from straws for a demonstration in class • "Let's Work" • Triangular Panels • Pipe Cleaners • Straws • Ruler, Scissors • Graph Paper, Construction Paper • Elastics	• Geometry: Solid Figures • Scale Drawing and Scale Models • Measurement: Surface Area • Measurement: Volume

During Class:

- Explain to students that each mission involves certain jobs and experiments that the astronauts must complete.
  - Many current experiments involve learning about techniques for building in space.
  - A recent experiment planned by MIT asked astronauts to build a tetrahedron in space.

- Discuss how building in space is quite different from building on earth.
  - The materials can be lighter.
  - All tools and materials must be anchored.

- Ask students to read about the Project EASE and complete "Let's Work".

Extensions

- Possible topics for discussion:
  - Why/what experiments are better done in space?
  - What constraints limit orbital operations?
  - Why is it easier to build a space station in space than on earth?
- Problem Cards #22, 24
- Examine "Another Building Shape". Pose questions similar to those for the tetrahedron.

Name ______________________

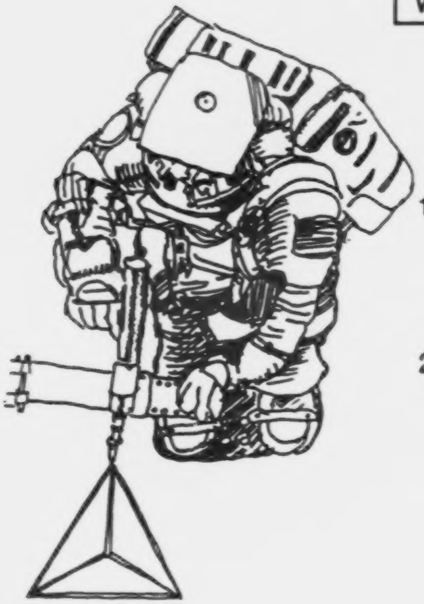
LET'S WORK

PROJECT EASE

A RECENT EXPERIMENT TO LEARN ABOUT WORKING IN SPACE WAS DESIGNED BY SCIENTISTS AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT).

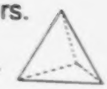
THE TASK WAS TO BUILD A TETRAHEDRON IN SPACE USING SIMPLE TOOLS, LONG RODS, AND SIMPLE CONNECTORS.

SCIENTISTS STUDIED THE TIME AND EASE WITH WHICH THE ASTRONAUTS DID THE JOB.



ASTRONAUT'S WORK ORDERS

1. Make a tetrahedron with straws and pipe cleaners. Each straw should be 6" long.
A reminder: a tetrahedron is a pyramid with four equal triangular faces.

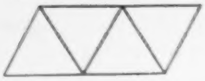


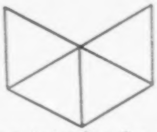
2. Estimate the height of the tetrahedron.

About your tetrahedron:
a. How many faces does it have?____________
b. What shape is each face?____________
c. How many vertices?____________
d. How many edges?____________

3. Why is a tetrahedron a useful building shape?

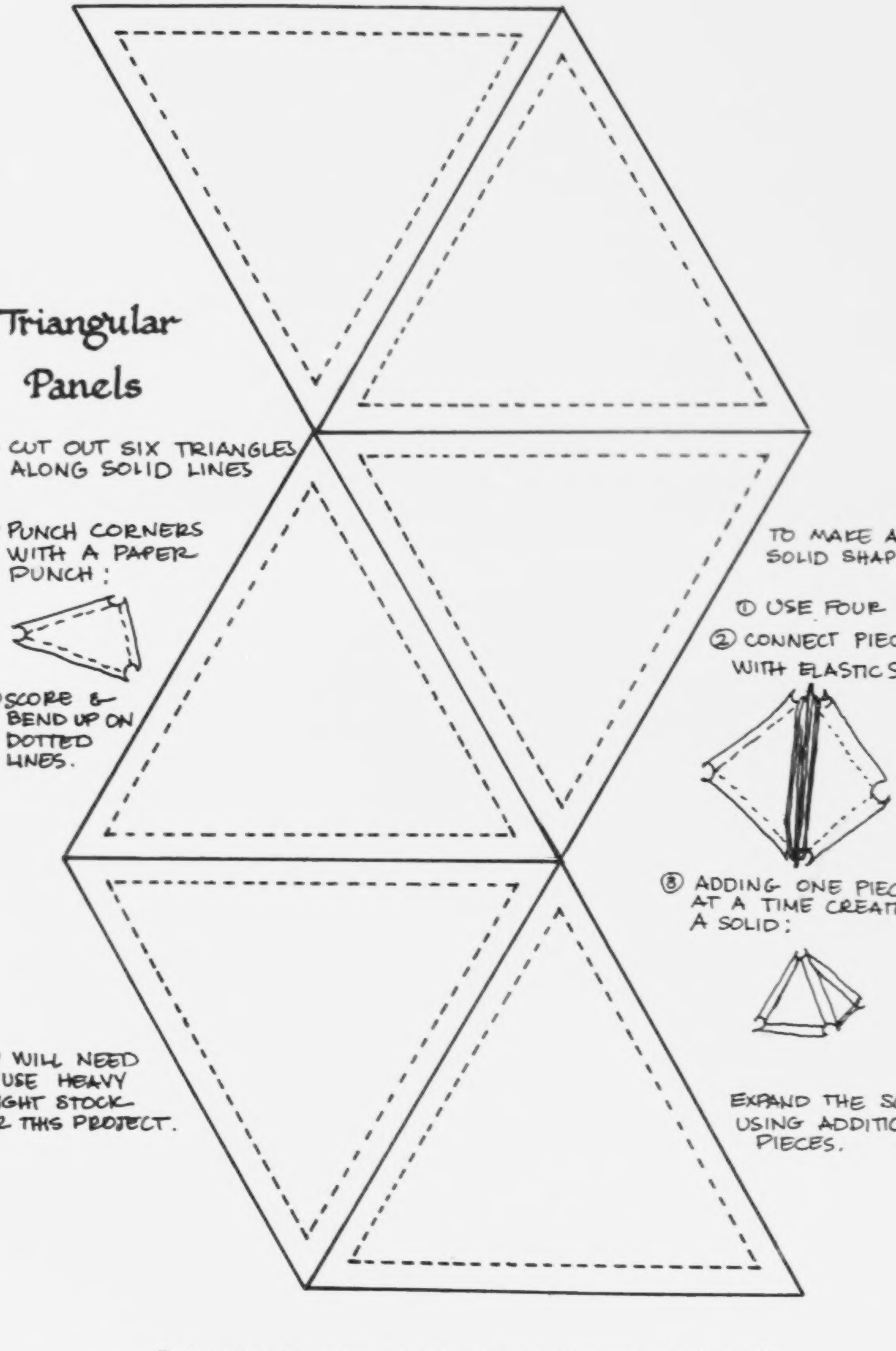
4. Which of these is a "net" of a tetrahedron?
A net is the two dimensional representation that when folded together will produce a three dimensional model.





5. Is there another possible "net" for a tetrahedron? Draw it.

Triangular Panels



① CUT OUT SIX TRIANGLES ALONG SOLID LINES

② PUNCH CORNERS WITH A PAPER PUNCH:

③ SCORE & BEND UP ON DOTTED LINES.

YOU WILL NEED TO USE HEAVY WEIGHT STOCK FOR THIS PROJECT.

TO MAKE A SOLID SHAPE:

① USE FOUR PIECES

② CONNECT PIECES WITH ELASTICS

③ ADDING ONE PIECE AT A TIME CREATE A SOLID:

EXPAND THE SOLID USING ADDITIONAL PIECES.

Name ______________________________

...FINISHING THE JOB

1. Cut out several triangular panels. Make a tetrahedron with triangular panels and elastics. The tetrahedron will be stronger if the panels are traced onto stiff paper and then cut out.

2. How many different solid shapes can you make using equilateral triangles? You may need to cut out more panels.

3. Estimate the dimensions of your tetrahedron, if the length of one side is 3". Use graph paper, ruler, and the tetrahedron "net" as needed.

   - Approximate Height = __________
   - Approximate Surface Area = __________
   - Approximate Volume = __________

4. On your tetrahedron model, let one inch represent a length of 20 feet.

   Estimate:

   - Surface Area of a 60' tetrahedron: __________
   - Volume of a 60' tetrahedron: __________

Name ____________________

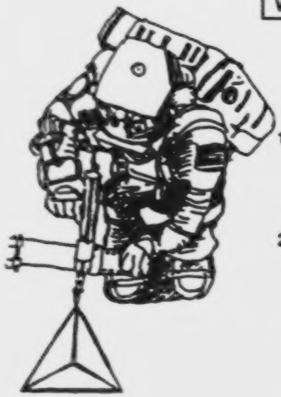
LET'S WORK

PROJECT EASE

A RECENT EXPERIMENT TO LEARN ABOUT WORKING IN SPACE WAS DESIGNED BY SCIENTISTS AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT).

THE TASK WAS TO BUILD A TETRAHEDRON IN SPACE USING SIMPLE TOOLS, LONG RODS, AND SIMPLE CONNECTORS.

SCIENTISTS STUDIED THE TIME AND EASE WITH WHICH THE ASTRONAUTS DID THE JOB.



ASTRONAUT'S WORK ORDERS

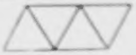
1. Make a tetrahedron with straws and pipe cleaners. Each straw should be 6" long.
A reminder: a tetrahedron is a pyramid with four equal triangular faces.

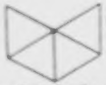
2. Estimate the height of the tetrahedron.

About your tetrahedron:
a. How many faces does it have? 4
b. What shape is each face? triangle
c. How many vertices? 4
d. How many edges? 6

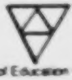
3. Why is a tetrahedron a useful building shape?

4. Which of these is a "net" of a tetrahedron?
A net is the two dimensional representation that when folded together will produce a three dimensional model.




✓

5. Is there another possible "net" for a tetrahedron? Draw it.
yes



Name ____________________

...FINISHING THE JOB

1. Cut out several triangular panels. Make a tetrahedron with triangular panels and elastics. The tetrahedron will be stronger if the panels are traced onto stiff paper and then cut out.

2. How many different solid shapes can you make using equilateral triangles? You may need to cut out more panels.

3. Estimate the dimensions of your tetrahedron, if the length of one side is 3". Use graph paper, ruler, and the tetrahedron "net" as needed.

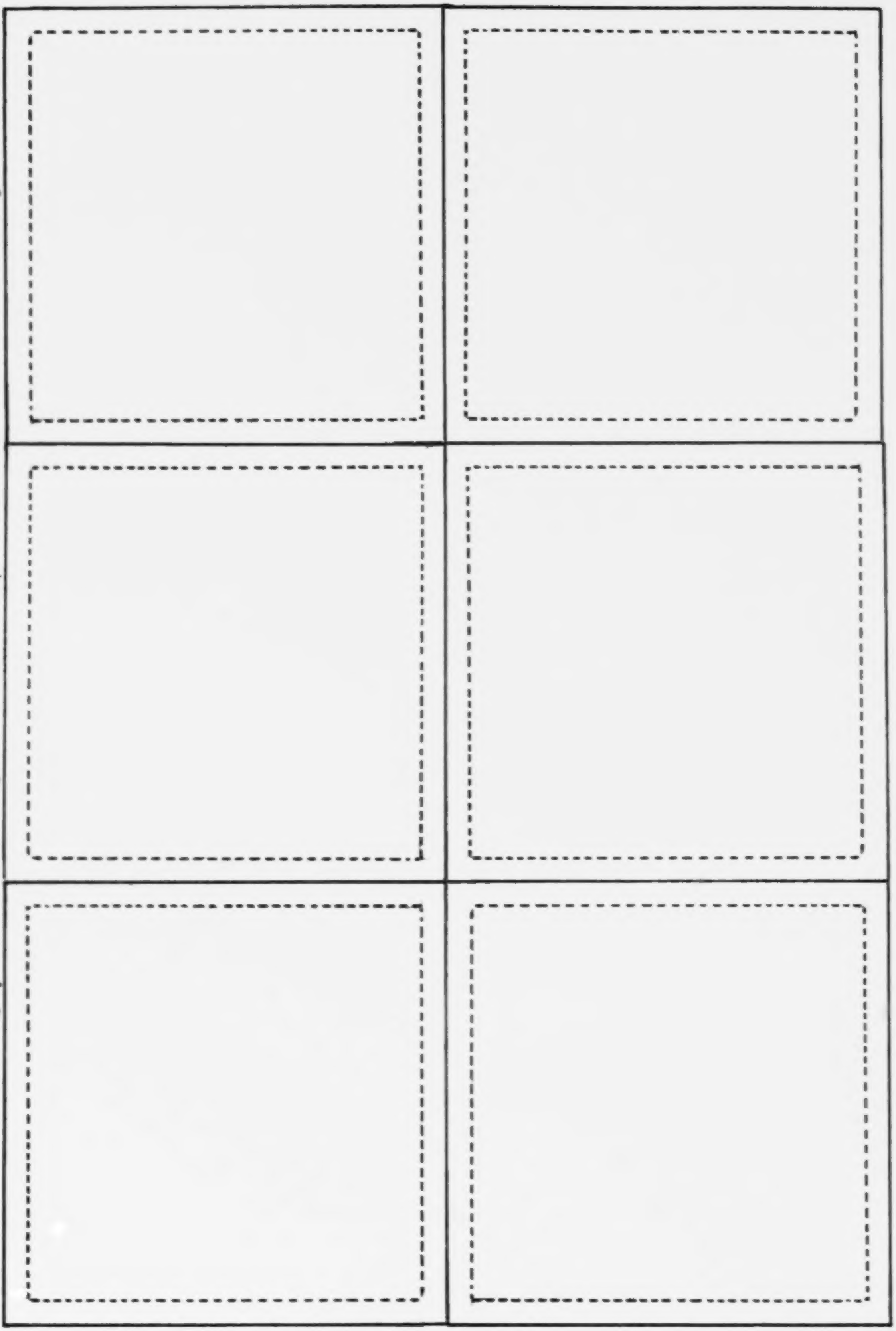
- Approximate Height = ≃ 2.4 inches.
- Approximate Surface Area = ≃ 16 sq. in.
- Approximate Volume = ≃ 2 cu in.

4. On your tetrahedron model, let one inch represent a length of 20 feet.

Estimate: H ≈ 48'

- Surface Area of a 60' tetrahedron: ≈ 6240 sq ft.
- Volume of a 60' tetrahedron: ≈ 25,000 cu ft.

Another building panel - see 'Triangular Panels' - six pieces will make a solid. Squares & triangles can be combined.



PLANNING FOR LIFE ON BOARD...

LET'S EXPERIMENT...

Preparation/Materials	**Math Skills**
- "Let's Experiment" - Calculators (Optional)	- Geometric Solid: Cylinder - Measurement: Surface Area - Measurement: Volume - Scale Drawing and Scale Models - Estimation in Computation

During class:

- Describe and discuss the recent GTE "Getaway Special" experiment sent up with the orbiter, using "Let's Experiment."

- Review the characteristics of cylinders used for the Getaway Specials, including:
  - the circular shape of base
  - surface area
  - volume

- Discuss with students the kinds of Getaway Specials that might be sent:
  - students research what local companies have done.
  - students speculate about the kinds of experiments that would benefit from the "weightlessness" of the space laboratory.
  - students discuss the limitations of the "space laboratory."

Extensions

- "Get Away Specials"
- Discuss packing strategies for payload bay.
- Find out about other experiments that have been sent up on shuttle missions.

LET'S EXPERIMENT

Name ______________________

The NASA "Get Away Special" (GAS) program enables private parties to "rent" space on on a Shuttle Mission. This was first advertised almost ten years ago.

The number of "specials" that a shuttle can carry depends on what else is on board, such as communications satellites. One recent Shuttle Mission was able to carry 12 "specials".

For $10,000, a payload will be carried that is contained in a cylinder providing 5 cubic feet of space to the user. The cylinder is approximately 19.75" in diameter and 28.25" long, with a 200 lb. limit.

For a cheaper price, $5,000, a 2.5 cubic foot of space, with a 100 lb weight limit, is available.

The "cut-rate" deal is for $3,000. You may rent a cylinder 14.5" in diameter and 19.75" in length, with a weight limit of 60 lb.

GTE Laboratories in Waltham was one of the many companies who took advantage of the offer. Ten years ago the President of GTE reserved four spots.

GTE rented the large cylinder. The GTE experiment was to examine high intensity lamps to determine the effects of gravity. The results showed light is brighter when there is no gravity.

The GTE payload included over 2000 parts which cost about $40,000. The total program costs about $750,000,000, including salaries and overhead.

1. Draw scale models of each of the cylinders. (Scale: 1" represents 4') on the back of this page.
2. Determine the approximate cost of renting a cubic inch of space in each cylinder.

LET'S EXPERIMENT

Name ____________________

The NASA "Get Away Special" (GAS) program enables private parties to "rent" space on on a Shuttle Mission. This was first advertised almost ten years ago.

The number of "specials" that a shuttle can carry depends on what else is on board, such as communications satellites. One recent Shuttle Mission was able to carry 12 "specials".

For $10,000, a payload will be carried that is contained in a cylinder providing 5 cubic feet of space to the user. The cylinder is approximately 19.75" in diameter and 28.25" long, with a 200 lb. limit.

For a cheaper price, $5,000, a 2.5 cubic foot of space, with a 100 lb weight limit, is available.

The "cut-rate" deal is for $3,000. You may rent a cylinder 14.5" in diameter and 19.75" in length, with a weight limit of 60 lb.

GTE Laboratories in Waltham was one of the many companies who took advantage of the offer. Ten years ago the President of GTE reserved four spots.

GTE rented the large cylinder. The GTE experiment was to examine high intensity lamps to determine the effects of gravity. The results showed light is brighter when there is no gravity.

The GTE payload included over 2000 parts which cost about $40,000. The total program costs about $750,000,000, including salaries and overhead.

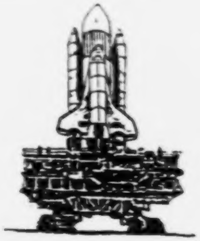
1. Draw scale models of each of the cylinders. (Scale: 1" represents 4') on the back of this page.
2. Determine the approximate cost of renting a cubic inch of space in each cylinder.

19.75" x 28.25" cylinder $1.16 cu. in

14.5" x 19.75" cylinder $ .92 cu in

Name ____________________

"GET AWAY SPECIALS"



1. AT&T has a new inter-communications satellite it wants to launch on the next mission. The satellite weighs 2.46 tons. At a rate of $52 per pound, how much would NASA charge AT&T?

2.46 tons ≈ 2.5 x 2000 lbs
≈ 5000 lbs.
costs ≈ $260,000

At the "Get away special" rate, what would the cost be?

200 lb rate ≈ $10,000
cost ≈ 25 x 10,000 = $250,000

2. The payload bay can carry 29.5 tons. At $52 per pound, how much would NASA charge if the payload bay were completely filled?

29.5 ≈ 30 x 2000 lbs
≈ 60,000 lbs
costs ≈ 52 x 60,000 = $3,120,000

At the "Get away special" rate, what would the cost be?

cost ≈ 300 x 10,000 = $ 3,000,000

3. Find the volume of the payload bay:

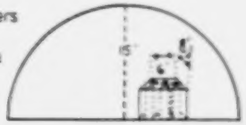
Height is approximately 15'
Length is 37.5'

$V \approx \frac{3(15^2) \times 38}{2}$

The formula for the volume of a cylinder is $V = \pi(\text{radius})^2 \times \text{length}$ $= 12,825$ cu ft.

So the volume of the payload bay is $\frac{\pi(\text{radius})^2 \times \text{length}}{2}$

- Imagine the payload bay contains six "Get away special" cylinders packed as shown in a crate which is the exact height of the cylinders. How much styrofoam would be needed to fill the extra area in the box if:



- The cylinders are large (19.75" diameter X 28.25" high)?

volume of crate = 96" x 72" x 28" = 193,536 cu in.
volume of one cylinder ≈ (3)·(10)²·28" ≈ 8400 cu in.
6 x 8400 = 50,400 cu in.
styrofoam = 193,536 − 50,400
≈ 143,100 cu in.

- The cylinders are mid-size "specials" (19.75" diameter X 14.25" high)?

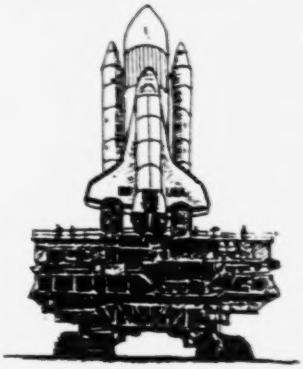
volume of crate ≈ 96" x 72" x 14" ≈ 97,000 cu in.
volume of one cylinder ≈ 3·(10²)·14" = 4200 cu in.
6 x 4200 = 25,200 cu in.
styrofoam = 97,000 − 25,200
≈ 71,800 cu in.

- The cylinders are cut rate "specials" (14.5" diameter X 19.75" high)?

volume of crate ≈ 138,000 cu in.
volume of one cylinder ≈ 3375 cu in.
styrofoam ≈ 138,000 − 20,250 ≈ 117,800 cu in.

Name ______________________

"GET AWAY SPECIALS"



1. AT&T has a new inter-communications satellite it wants to launch on the next mission. The satellite weighs 2.46 tons. At a rate of $52 per pound, how much would NASA charge AT&T?

   At the "Get away special" rate, what would the cost be?

2. The payload bay can carry 29.5 tons. At $52 per pound, how much would NASA charge if the payload bay were completely filled?

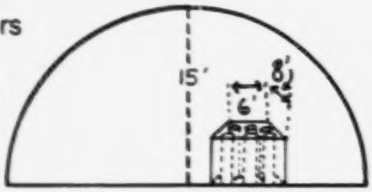
   At the "Get away special" rate, what would the cost be?

3. Find the volume of the payload bay:

   Height is approximately 15'
   Length is 37.5'

   The formula for the volume of a cylinder is $V = \pi(\text{radius})^2 \times \text{length}$

   So the volume of the payload bay is $\frac{\pi(\text{radius})^2 \times \text{length}}{2}$



- Imagine the payload bay contains six "Get away special" cylinders packed as shown in a crate which is the exact height of the cylinders. How much styrofoam would be needed to fill the extra area in the box if:

  - The cylinders are large (19.75" diameter X 28.25" high)?

  - The cylinders are mid-size "specials" (19.75" diameter X 14.25" high)?

  - The cylinders are cut rate "specials" (14.5" diameter X 19.75" high)?

3,2,1
BLAST OFF!

Preparation/Materials	**Math Skills**
• "3,2,1 Blast-Off"	• Use of Formulae • Estimation in Computation • Conversion of Units

During class:

- Discuss:
  - The launch and the g-forces experienced by the astronauts;
  - Training in the centrifuge to become accustomed to the g-forces;
  - The similarity of the centrifuge to familiar amusement rides.
- Ask students to complete the exercise about g-forces, "3,2,1 Blast-Off."

Extension

- "The Gemini Capsule"
- Journal Entry: If you could take only one thing on the trip, what would it be? Why might you not want to go?
- "Toys in Space"

Name ______________________

3, 2, 1 BLAST OFF

At lift-off, an astronaut experiences a force of 3 g's. This means astronauts feel three times their weight on earth. To train for these g-forces, astronauts spin around in a centrifuge. As the turning is increased, the astronaut feels stronger forces and therefore more g's.

Each of you has probably also travelled on a centrifuge. A centrifuge is simply a vehicle that travels a circular route at a very fast speed. At amusement parks, you often ride on rides that go around in circles at a fast speed.

To calculate the number of g's a rider feels, this formula is used.

$$\text{g's} = \frac{4 \times \pi^2 \times (\text{Distance from the Turning Center})}{32 \times (\text{Turning Period})^2}$$

The turning period is the time it takes for a rider to make one turn.

1. A Merry-Go-Round is like a centrifuge. Our Merry-Go-Round is 32' in diameter. The circumference (distance around) is 32π or about 96'(π is approximately 3). If the Merry-Go-Round completes a turn in 8 seconds, how many g's would you feel?

   What is the approximate comparable speed in miles per hour?

2. About how long should the Merry-Go-Round take to complete a turn so that astronauts feel 3 g's?

   Approximately how fast would that be in m.p.h.?

Name ____________________

3, 2, 1 BLAST OFF

At lift-off, an astronaut experiences a force of 3 g's. This means astronauts feel three times their weight on earth. To train for these g-forces, astronauts spin around in a centrifuge. As the turning is increased, the astronaut feels stronger forces and therefore more g's.

Each of you has probably also travelled on a centrifuge. A centrifuge is simply a vehicle that travels a circular route at a very fast speed. At amusement parks, you often ride on rides that go around in circles at a fast speed.

To calculate the number of g's a rider feels, this formula is used.

$$g\text{'s} = \frac{4 \times \pi^2 \times (\text{Distance from the Turning Center})}{32 \times (\text{Turning Period})^2}$$

The turning period is the time it takes for a rider to make one turn.

1. A Merry-Go-Round is like a centrifuge. Our Merry-Go-Round is 32' in diameter. The circumference (distance around) is 32π or about 96' (π is approximately 3). If the Merry-Go-Round completes a turn in 8 seconds, how many g's would you feel?

   $g \approx .28 \approx .3$

   What is the approximate comparable speed in miles per hour?

   speed ≈ 8.1 M.P.H.

2. About how long should the Merry-Go-Round take to complete a turn so that astronauts feel 3 g's?

   $t \approx \sqrt{6}$ sec.

   $t \approx 2.5$ sec.

   Approximately how fast would that be in m.p.h.?

   speed ≈ 26 M.P.H.

Name ____________________

COMPLETING THE RIDE...

1. A rider who feels 8 g's typically loses consciousness. In how many seconds must the merry-go-round complete a turn to produce a force of 8 g's?

   1.5 sec

2. Estimate its speed in miles per hour if it takes 3 seconds to complete a turn.

   22 m.p.h.

3. Find the forces exerted by the Merry-Go-Round if it takes...

Seconds to complete turn	1	2	3	4	5	6	7	8
Its speed in miles per hour	65 mph	33 mph	22 mph	15 mph	13 mph	11 mph	10 mph	9 mph
Number of g's felt by a rider	18	4.5	2	.9	.7	.5	.4	.3

Name____________________

COMPLETING THE RIDE...

1. A rider who feels 8 g's typically loses consciousness. In how many seconds must the merry-go-round complete a turn to produce a force of 8 g's?

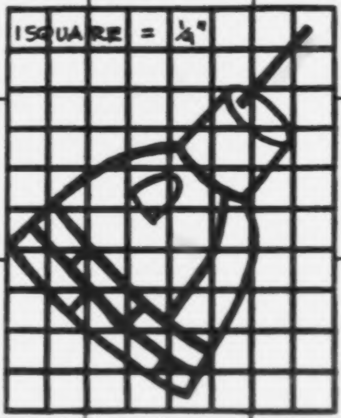
2. Estimate its speed in miles per hour if it takes 3 seconds to complete a turn.

3. Find the forces exerted by the Merry-Go-Round if it takes...

Seconds to complete turn	1	2	3	4	5	6	7	8
Its speed in miles per hour	65 mph	33 mph		15 mph	13 mph	11 mph	10 mph	9 mph
Number of g's felt by a rider								

1 SQUARE = 1"

Name ____________________



THE GEMINI CAPSULE WAS ONE OF OUR FIRST SPACE EXPLORATION VEHICLES.

ENLARGE THE GEMINI CAPSULE TO A 1" SCALE.

How many times larger in area is your drawing than the original drawing? ____

TOYS IN SPACE

Preparation / Materials	Math Skills
• Preview "Toys in Space" with the Fact Book • Selected Toys from "Toys in Space" Experiments	• Prediction and Problem Solving

During class:

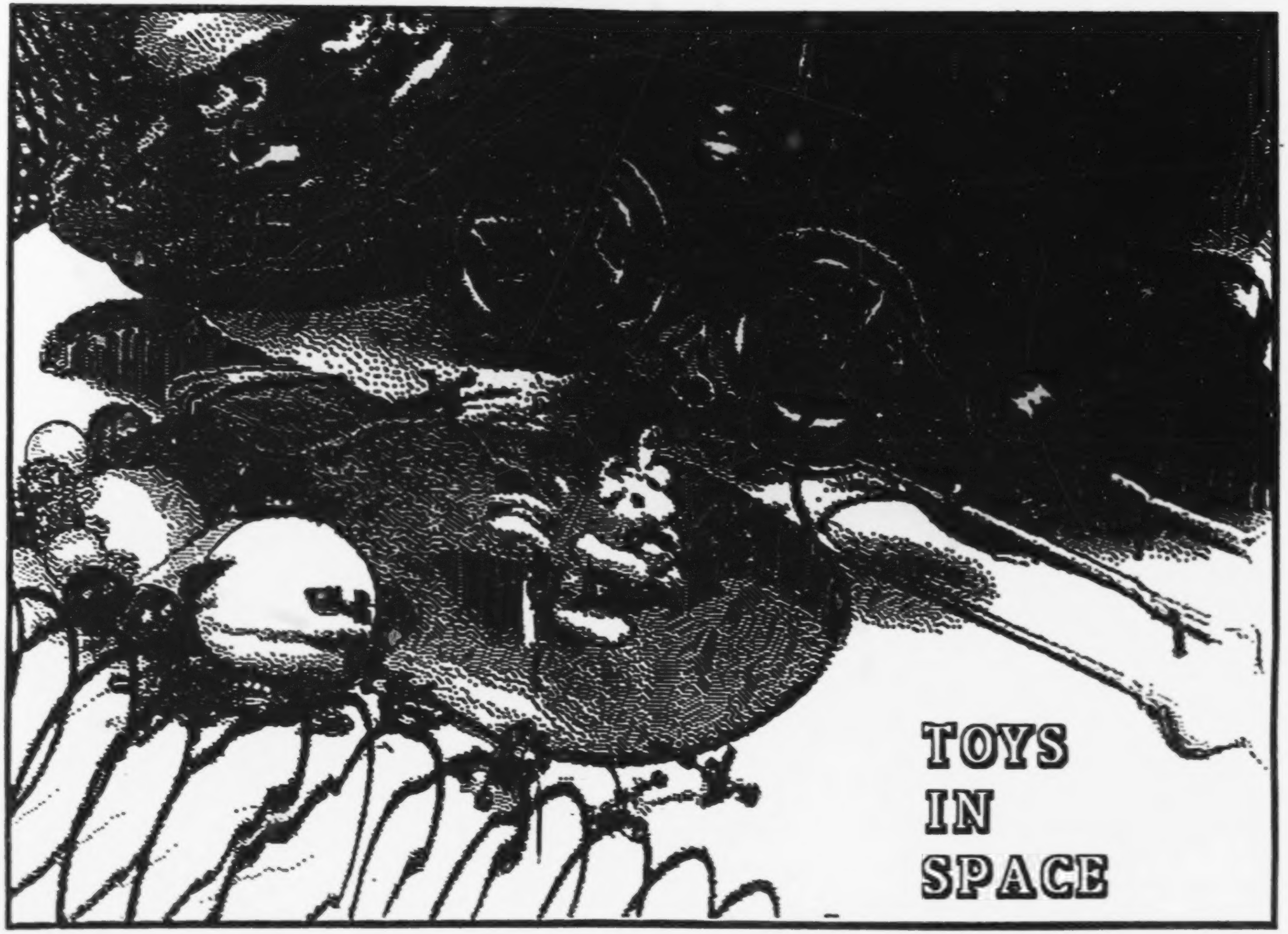
- Discuss the Toys in Space project
  - Gravity's downward pull dominated the behavior of toys on earth. It is hard to imagine how a familiar toy would behave in weightless conditions. Discover gravity by playing with the toys that flew in space. Try the experiments described in the guide. Decide how gracity affects each toy's behavior. If possible, watch the Toys in Space videotape or study a Toys in Space poster. To check your predictions, read the results sections of the guidebook. Finish your Toy investigation with a Twenty Toy Questions challenge.
  - On April 12, 1985 at 7:59 a.m. CST, the Space Shuttle Discovery transported eleven familiar motion toys into the weightless environment of space. In turn, each toy carried along the questions of all the curious children, teachers, and parents who had suggested toy experiments and predicted possible results. Twenty dollars worth of toys and several hours of free time donated by five enthusiastic astronauts and one space-bound senator brought the experience of weightlessness and an understanding of gravity's pull to students of all ages.
- Select an experiment(s) to investigate.

Extensions

- Select Other Toys from "Toys in Space Project".

Regional Math Network • Harvard Graduate School of Education • Harvard University

Twenty Toy Question Answers:
1-a, 2-c, 3-a, 4-b, 5-d, 6-c, 7-b, 8-a, 9-b, 10-d, 11-b,
12-a, 13-c, 14-d, 15-a, 16-c, 17-a, 18-b, 19-a, 20-c



TOYS IN SPACE

RESULTS
of the
SPACE SHUTTLE MISSION
STS - 51D

INTRODUCTION

Gravity's downward pull dominates the behavior of toys on earth. It is hard to imagine how a familiar toy would behave in weightless conditions. Discover gravity by playing with the toys that flew in space. Try the experiments described in this guidebook. Decide how gravity affects each toy's performance. Then make predictions about toy space behaviors. If possible, watch the Toys in Space videotape or study a Toys in Space poster. To check your predictions, read the results sections of the guidebook. Finish your Toy investigations with a Twenty Toy Questions challenge.

CREDITS

Toys In Space developer: Dr. Carolyn Sumners, Director
of Astronomy & Physics
Houston Museum of Natural Science
Guidebook layout & design: Gary Young,
Vela Productions
Poster & Guidebook illustration: Chris Meister,
Vela Productions
Toys In Space videotape production: Pat Schwab,
KPRC Television, Channel 2

The illustrations from this Toys In Space Guidebook will also appear in the book Toys In Space - Learning Science while Having Fun - by Dr. Sumners

All photographs of toys performing in space are courtesy of the National Aeronautics and Space Administration.

THE TOYS IN SPACE PROJECT

On April 12, 1985 at 7:59 a.m. CST, the Space Shuttle Discovery transported eleven familiar motion toys into the weightless environment of space. In turn, each toy carried along the questions of all the curious children, teachers, and parents who had suggested toy experiments and predicted possible results. Twenty dollars worth of toys and several hours of free time donated by five enthusiastic astronauts and one space-bound senator could bring the experience of weightlessness and an understanding of gravity's pull to students of all ages.

This toy cargo gave the Space Shuttle one more role in extending human access to the space environment. With the addition of a few pounds of toys, the Shuttle mid-deck became a space classroom where astronauts could teach the nation's children about life in space.

THE TOYS IN SPACE CREW

COMMANDER KAROL BOBKO	-- gyroscope and metal top
PILOT DONALD WILLIAMS	-- paddleball and "Rat Stuff" - the flipping mouse
DR. JEFFERY HOFFMAN	-- wind-up car, wheelo, and magnetic marbles
DR. RHEA SEDDON	-- slinky, ball and jacks
DAVID GRIGGS	-- yo-yo
SENATOR JAKE GARN	-- paper airplane

PHYSICS BASICS

0. **GRAVITY:** On the earth's surface, all objects experience a downward force caused by the gravitational attraction between the object and the earth. THE BEHAVIOR OF ANY TOY ON EARTH IS AFFECTED TO SOME EXTENT BY GRAVITY'S PULL.

1. **MICROGRAVITY:** The earth's GRAVITY keeps satellites and their contents in orbit. The satellites travel so quickly that they do not fall toward the earth. Astronauts inside feel as if they are falling freely like a diver jumping off a diving board. This experience is also called "weightlessness" or "zero gravity". Microgravity is the official term because there are small forces still felt in the Space Shuttle when the spacecraft maneuvers in orbit. THE TOYS ON SHUTTLE FLOAT THROUGH THE CABIN WITHOUT EXPERIENCING ANY DOWNWARD FORCE RELATIVE TO THE SPACECRAFT.

2. **ENERGY CONSERVATION:** When an object moves, it has Kinetic Energy. AN ASTRONAUT TRYING TO MOVE A TOY MUST FIND A SOURCE FOR THE ENERGY NEEDED BY THE TOY.

3. **MOMENTUM CONSERVATION:** Objects in motion have momentum. More massive faster moving objects have more momentum. In a collision, momentum is conserved. When one object loses momentum, another object must gain momentum. This momentum conservation is also described as a REACTION FORCE produced by an object for every ACTION FORCE acting on the object. THE RESULTS OF MANY TOY COLLISIONS ARE DETERMINED BY THIS CONSERVATION LAW.

4. **INERTIA:** Objects in motion tend to stay in motion. Objects at rest tend to stay at rest. An astronaut must exert a force to cause a toy to change its motion. It requires more force to move an object with more mass. If an astronaut tries to make a toy turn or move in a circle, the inward action force exerted on the toy is called a CENTRIPETAL FORCE. The outward reaction force produced by the toy is called the CENTRIFUGAL FORCE. GRAVITY PROVIDES THE CENTRIPETAL FORCE THAT KEEPS THE SPACE SHUTTLE IN ORBIT.

5. **ANGULAR MOMENTUM CONSERVATION:** Spinning objects have angular momentum. More massive, more spread-out, and more rapidly spinning objects have more angular momentum. Angular momentum must be conserved. A SPINNING TOY WILL CONTINUE SPINNING WITH THE SAME AXIS TILT UNTIL IT TRANSFERS SOME OF ITS ANGULAR MOMENTUM TO ANOTHER OBJECT - SUCH AS A SUPPORTING TABLE.

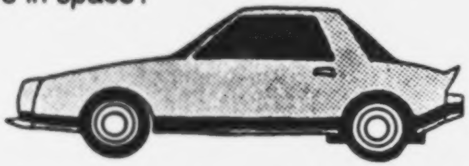
THE TOYS FROM SPACE

The manufacturers listed below produce the actual off-the-shelf toys that flew in space. In many cases an equivalent toy can be used instead.

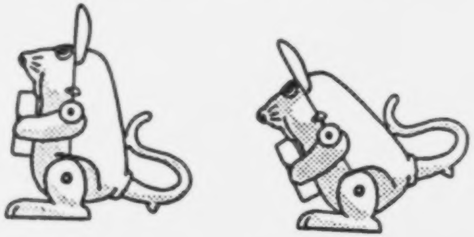
1. **"Rat Stuff":** a pop-over mouse by Tomy Corp., Carson, CA 90745. The pop-over kangaroo or gorilla may be used.
2. **Yo-Yo:** flight model is a yellow Duncan Imperial model by Duncan Toy Company, Baraboo, WI. 53913. Any good sleeper yo-yo will work.
3. **Wheelo:** flight model by Jak Pak, Inc., Milwaukee, WI., 53201. Other models work as well.
4. **"Snoopy" Top:** flight model by Ohio Art, Bryan, OH. 43506. Any metal top can be used.
5. **Slinky:** Model #100 made by James Industries, Inc., Hollidaysburg, PA. 16648. The flight version was "blued" to photograph better.
6. **Gyroscope:** flight model by Chandler Gyroscope Mfg. Co., Hagerstown, IN. 47346. Any well-balanced gyroscope can be used.
7. **Magnetic Marbles:** sold in packages of 12 or 20 by Magnetic Marbles Inc, Woodinville, WA. 13 marbles flew.
8. **Wind-Up Car:** red Camaro from the Darda Toy Company, East Brunswick, NJ. Circular track from larger kit.
9. **Jacks:** flight set made by the Wells Mfg. Cl., New Vienna, OH 45159. Any jacks can be used.
10. **Paddleball:** flight model by Chemtoy, a division of Strombecker Corp., Chicago, IL 60624. Any equivalent version can be used.

EXPERIMENT 1: MOVING ALONG

Three motion toys went into space: a wind-up car, a paper airplane, and a flipping mouse. Push the car along a table to wind it up. Release it. Try different surfaces. On what surface does it go fastest? Tilt the surface upward. How is the speed affected? Would the car move in space?



Make a standard airplane. Fly it forward. Fly it backward. Is there a difference? Make a runway for your plane. Is it hard to land the plane accurately? Try to make a plane that spins and one that does loops. Discover how wing flaps make a plane turn.



Wind up Rat Stuff, the flipping mouse. Set him on a smooth flat surface. Watch him flip. Tilt the surface. What happens? Make the surface soft. What happens? How does Rat Stuff use the bump on his tail? Put marshmallows on Rat Stuff's ears. Does it change his flip?

EXPERIMENT 2: SPIN STABILITY

Start a gyroscope or top spinning. Try to tilt its spin axis. What happens? Push a spinning gyroscope or top with a string. How does it move? Try balancing a gyroscope on your finger, on a string, or on another spinning gyroscope. What happens? Watch a top or gyroscope slow down. What happens to the spin axis?

EXPERIMENT 3: SPIN ENERGY

Watch a yo-yo in action - moving down and up the string. Unwind a yo-yo string. Hang the yo-yo at the bottom of the string. Try to make it climb the string. What determines whether or not a yo-yo will climb upward? Where does the yo-yo get the energy needed to climb upward? Give a yo-yo a lot of spin as you throw it downward. Relax your hand as it reaches the end of the string. See if the spinning yo-yo will stay there until you jerk your hand to bring it up. This is "sleeping" the yo-yo.

Tilt a wheelo up and down as the wheel rolls. You are using gravity to start the wheel spinning. You can start the wheel without gravity. Experiment to find out how. Remember, you must not tilt the track. Get the wheel spinning and then stop moving the track. Where does the wheel get the energy needed to keep moving? What keeps the wheel on the track as it moves through the bend?

See how fast you can move the wheel. Where on the track does the wheel finally fly off?

EXPERIMENT 4: THE BOUNCING BALL

Play paddleball downward, upward, and sideways. Which is easiest? Why? Hit the ball softly. Hit the ball hard. Which works better? Why? Shorten the elastic string. Is it harder or easier to paddle? Why? When is the paddleball ball going fastest?

When playing jacks, you must bounce the ball, pick up a jack, and catch the ball. After picking up all the jacks in this manner, try to pick up two jacks at a time while the ball is bouncing. Then try for three jacks, four jacks, and so forth. What is the best toss and catch strategy? Would it be easier to play with a very bouncy ball or a flat ball?

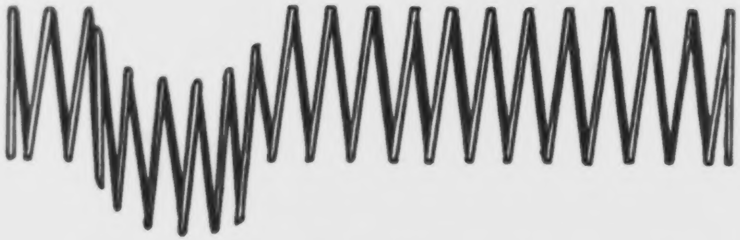
EXPERIMENT 5: MAGNETIC MOTIONS

See how many marbles you can pick up with just one marble. The more marbles you pick up, the stronger the magnetic force. Toss up groups of marbles arranged in lines and circles. Which arrangements are stable? Move two circles of 6 marbles together. What happens when they touch? Turn one of the circles over. Push the circles together again. Does the same thing happen? Roll two marbles into each other. See if you can make them spin. Arrange three marbles in a triangle. Put a fourth marble on top to make a pyramid. Be careful. It can be done.

EXPERIMENT 6: SLINKY WAVES

Stretch out a slinky. Move one hand back and forth - pushing in and pulling out on the slinky. Watch the waves travel along the slinky. Does the wave stop when it reaches your other hand? Does the whole slinky move from one hand to the other? These compression waves are like sound waves traveling through the air. Your ear can detect the changes in air pressure as the sound wave strikes your ear drum. Your mind interprets the vibration as sound.

Stretch out a slinky. Move it from side to side with one hand. Watch these waves move along the slinky. This is a transverse wave. Light waves and water waves are transverse waves. What happens to this wave when it reaches your other hand? Move the slinky back and forth faster and faster. See if you can get the wave moving at just the right speed so that at least one place on the slinky stays still as the wave moves up and down around it. This is a standing wave.



MAKING TOY PREDICTIONS

GYROSCOPE AND TOP: In space:

1. Will a spinning gyroscope or top spin faster or longer?
2. Will a spinning object wobble as it slows down?
3. Will a spinning object move along a string?
4. If a spinning gyroscope is swung around in circles by an attached string, how will its axis orient?
5. Will it be possible to start a push knob top?

YO-YO: In space:

1. Can a yo-yo be yo-yoed at any speed?
2. Will a yo-yo return when it reaches the end of its string?
3. Will a yo-yo sleep?
4. What will a yo-yo do when the astronaut releases the string?
5. Which yo-yo tricks will be possible in zero gravity?

WHEELO: In space:

1. Will the magnetic wheel still stick to the track?
2. Can the wheel's motion be started and maintained?
3. Will the wheel continue to move on the track when the track is released?
4. Will the wheel continue to spin?
5. How will the wheelo system move when released?

MARBLES: In space:

1. If a marble chain is swung in circles, where will it break?
2. What will happen to two marbles that are tossed together?
3. What will happen when two rings of 6 marbles collide?
4. Will floating or tossed marbles stay together?
5. What will happen when a marble attaches to a marble chain?

SLINKY: In space:

1. Will a slinky walk?
2. What will happen when the slinky is stretched apart and released?
3. Can a slinky be rocked from hand to hand?
4. Will a slinky carry transverse or compression waves?
5. Can standing waves be formed in a slinky?

MORE TOY PREDICTIONS

PADDLEBALL: In space:

1. Will a paddleball's speed be faster or slower?
2. Will it be as easy to paddle in any direction?
3. Will a ball on a stretched string return to the paddle?
4. Will a paddleball player change his style?
5. If a paddleball is released after the ball is hit, will the paddleball paddle itself?

PAPER AIRPLANE: In space:

1. Will a standard paper airplane soar as well as it does on earth?
2. Can a paper airplane be flown as well backward as forward?
3. How will a paper airplane behave when released with no push?
4. What will happen to a paper airplane when it reaches a wall?
5. Can a paper airplane be thrown so that it makes a loop?

CAR ON CIRCULAR TRACK: In space:

1. Will turning wheels make the car move on a table?
2. Will a pushed car move forward?
3. Will there be friction between the car's wheels and the table?
4. Will a wound-up car move along a circular track at a constant speed?
5. Will the wheels of a friction car turn as the car moves along a circular track?

JACKS: In space:

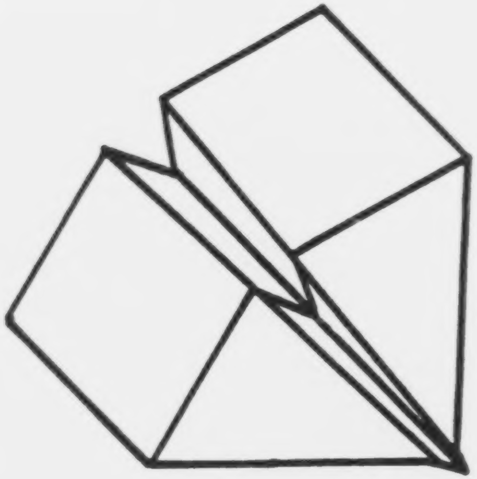
1. Will the ball bounce?
2. Will a moving ball slow down and speed up like it does on earth?
3. What will happen to the jacks when they are released?
4. How must the rules be changed for a game of jacks?
5. How will a spinning jack behave?

FLIPPING MOUSE ("RAT STUFF") In space:

1. Will Rat Stuff flip over?
2. Will Rat Stuff be able to flip off a wall?
3. Will Rat Stuff return to the table after a flip?
4. At what angle will Rat Stuff leave a wall?
5. After Rat Stuff leaves a wall, will he continue to flip?

THE SPACE PLANE:

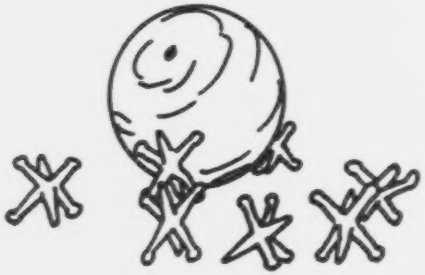
In space a paper airplane will soar farther than on earth. The airplane's shape is important. It must be aerodynamic. It will fly forward, but will NOT fly backward. When the airplane is released with no push, the airplane will drift in the air currents. When an airplane hits the wall, it will bounce off and float backward. In space, an astronaut can blow on a paper airplane to make it fly. A paper airplane should loop in space although no looping airplane was tried on Mission 51D.



If a standard paper airplane is released with a sideways push, the airplane will twist to the right or left as it soars forward.

THE SPACE JACKS:

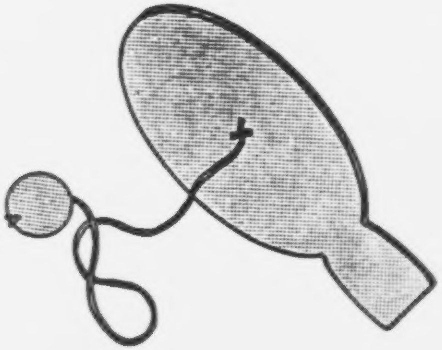
Playing jacks is a very different game in space. When the jacks player opens her hand, the jacks stick a bit to her fingers. As they leave her hand, they have some of the momentum from her opening fingers. This momentum makes the jacks drift apart. The jacks player must act quickly before the jacks move beyond her reach. If a more massive ball hits a lighter jack, it will cause the jack to fly away at a much faster speed. In a space jacks game, a dropped ball will not fall. The astronaut must throw the ball toward a wall and wait for the bounce and return. Any wall or the ceiling or floor can be used as a bouncing surface. The ball can also be tossed at any speed. Some minimum speed must be set so that the game is still challenging. If a tiny jack is given a spin, it will behave like a tiny gyroscope - keeping its spin orientation as it drifts through the air.



Once while collecting jacks, Astronaut Seddon lost her footing. As she grabbed for the jack, her momentum carried her forward. She tucked her body and caused a rolling motion and a flip as she conserved angular momentum.

THE SPACE PADDLEBALL.

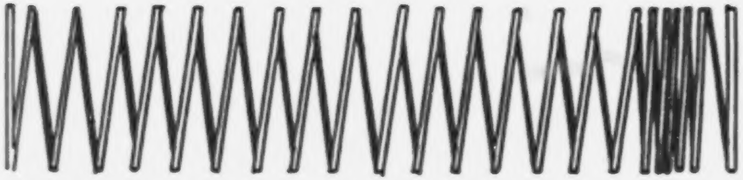
In space paddling a paddleball is much easier. The activity can be done in any direction. The ball will float outward as it gently stretches its string. Afterward it will return to the paddle. The whole activity appears to be in slow motion. To get the ball to return to the paddle instead of falling toward earth, the paddleball player must hit the ball much harder on earth than in space. The paddleball player's space style is more deliberate and graceful. If the ball and paddle are stretched apart and released, they will come back together. The paddle will twist because the string is not connected to the paddle's center of mass. As a result, when the ball reaches the paddle, the paddle is turned so that the ball passes by without any collision.



If the paddle is released after the ball is hit, the ball will reach the end of its stretch and return toward the paddle. Meanwhile the paddle will be pulled forward by the elastic string. Astronaut Don Williams was able to get the ball to return and bounce off the paddle once after he released the paddle.

THE SPACE SLINKY:

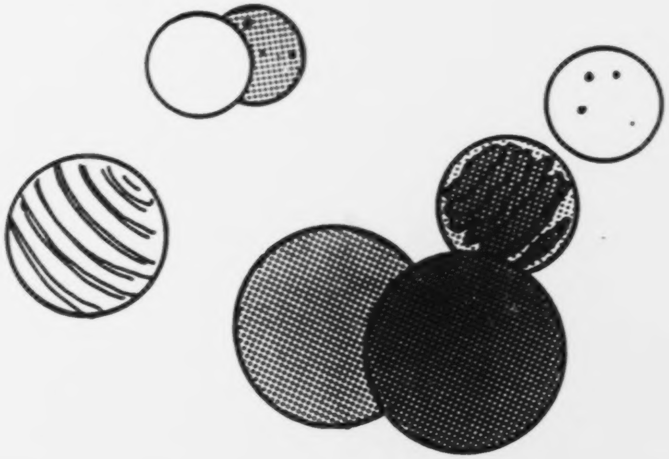
In space, the slinky will not walk. Instead it always returns to the hand holding onto it. The slinky coils can be pushed from hand to hand much as is done on earth. The space slinky can perform a yo-yo-like behavior. The astronaut pushes the yo-yo forward. The slinky moves outward until the coils are stetched. The spring action pulls the coils back toward the astronaut and outward behind him as the slinky's behavior repeats. If the slinky is stretched apart and released, it will come together and then turn slowly.



Astronauts Jeff Hoffman and Rhea Seddon discovered that the slinky will carry compression waves and transverse waves. When the coils on one end of the slinky are squeezed together and released, a compression wave travels along the slinky. When one end of the slinky is swung sideways, the slinky will carry a left to right transverse wave. When a wave reaches the end of the slinky, it will bounce back along the slinky. If the compression wave or transverse wave is continually sent along the slinky, a place or places on the slinky may stand still as the wave moves around them. This is called a standing wave, and the non-moving spots are called nodes.

THE SPACE MARBLES:

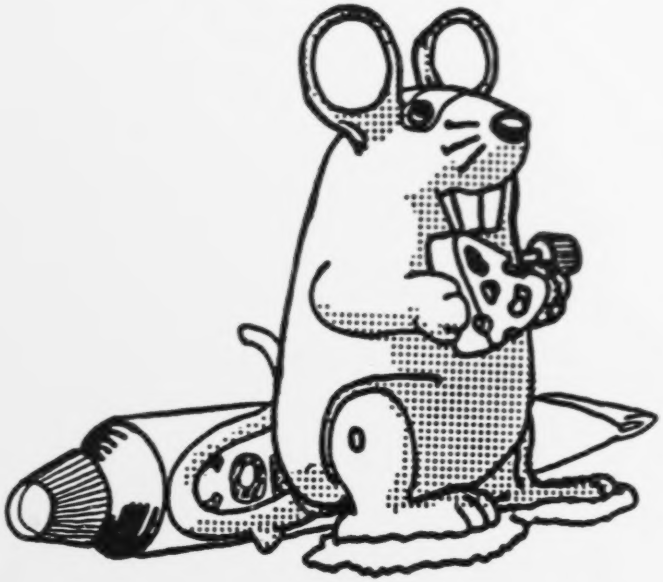
When two marbles are pushed together in space, they stick and begin to spin around their joining point. Tossed and floating marbles will stick together. As other marbles are pushed into the chain, they will attach to one end and cause the whole chain to oscillate. If enough marbles are added to the chain, the chain will move about so wildly that the two ends will come close enough for their magnetic attraction to close the chain into a circle. When the marble chain is swung around, inertial forces of the marbles trying to move in a straight line cause the chain to break. The chain always breaks between the first and second marbles - the ones closest to the center.



Astronaut Hoffman discovered that three things can happen when two six-marble circles are pushed together. The circles can repel. The circles can attach to form a figure-eight. The circles can attach to form a large circle.

"RAT STUFF", THE FLIPPING MOUSE

In space Rat Stuff could not stay on the wall long enough to flip. The astronauts used hand-cream to make the mouse's feet sticky enough to adhere to the wall. By the mission's end, the mouse also had a small strip of velcro to hold him to the velcro patches on the cabin wall. Astronaut Don Williams deployed Rat Stuff by winding it up and sticking it to the wall with a blob of hand cream as big as a pencil eraser.

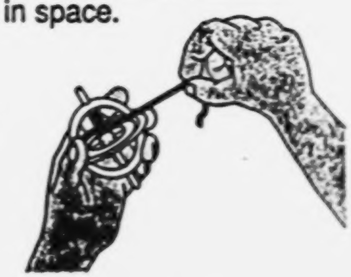


When Rat Stuff leaned forward and then jerked backward, its feet pushed against the wall. The wall reacted by pushing the mouse away in a straight out motion. The mouse continued to flip as it sailed quickly across the cabin.

THE GYROSCOPE AND TOP IN SPACE:

In space a spinning gyroscope can reach about the same spinning speed as it does on earth. Its spinning will cause its support cage to spin. Because there is no friction with a support surface, the gyroscope will spin much longer. Only air resistance gradually slows down the spinning space gyroscope. Gravity causes the wobble in a gyroscope or top. This wobble (officially called Precession) increases as the gyroscope slows down on earth. In space there is no force to cause a wobbling motion. When touched by a string, a spinning space gyroscope reacts by floating away. When attached to a string and swung around in circles, a spinning gyroscope will orient its axis to be perpendicular to the string.

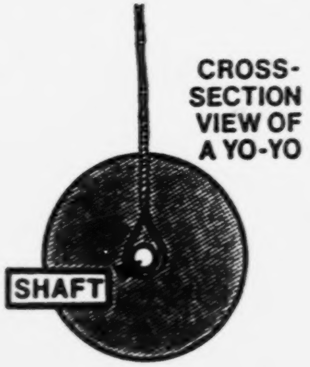
In space a push-top comes back up when the astronaut pulls up on the knob. To start the top, one hand must push downward on the top while the other pumps the knob up and down. For this reason, the top cannot reach the same spinning rate in space.



Commander Bobko demonstrated the value of gyroscopes by starting his gyroscope spinning and then circling around it. As he moved around, the gyroscope kept its orientation. There are gyroscopes inside the Shuttle's computer instrumentation that tell the Commander about the orientation of the Shuttle as it circles the earth.

THE SPACE YO-YO:

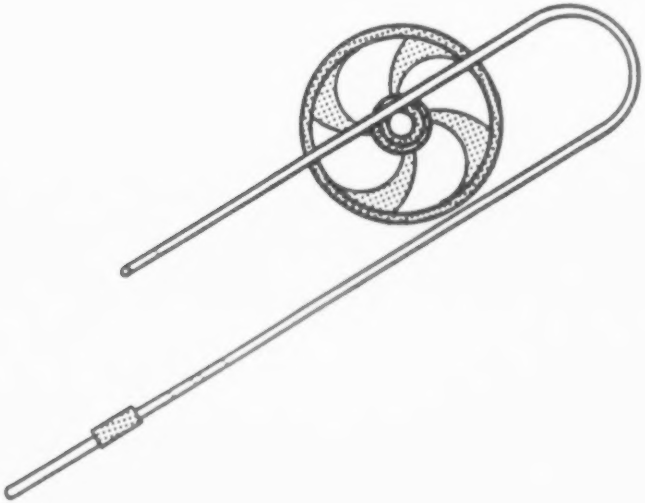
In space a yo-yo performs well at any speed. It will gracefully move down the string without tangling and bounce backward along the string when it reaches the loop at the end. The yo-yo will not sleep in space because there is no force to keep the yo-yo from moving back up the string. If the astronaut releases the yo-yo when it is coming back along the string, the yo-yo will continue to wind up its string as it moves past the astronaut. If the string is released on the way out, the yo-yo will wind up its string while moving forward. Yo-yo tricks involving sleeping the yo-yo (like "walking the dog" and "rocking the baby") cannot be performed in space. "Around the world" requires a sleeping yo-yo and too much room for an effective demonstration in the cabin.


CROSS-SECTION VIEW OF A YO-YO
SHAFT

Dynamic yo-yo tricks work beautifully in space. Astronaut Dave Griggs can send the yo-yo out, bring it back, and send it upward with little effort. On earth, this trick is called "shooting the moon."

THE SPACE WHEELO:

Magnetism is the same in space as on earth, so the wheel does stick to the track. By slinging the wheel sideways in a circular arc, Astronaut Hoffman could start the wheelo using a combination of inertia and centripetal force. In conserving momentum, the wheel will continue moving along the track after the track is released. It will continue spinning to conserve angular momentum. It transfers some of its angular momentum to the track as the track also begins to turn.



If the wheelo is released as the wheel is moving away, the wheel will pull the track away with it -- especially when the wheel turns the curve in the track.

SPACE CAR ON A CIRCULAR TRACK.

The car carried into space had an engine that could be wound-up by turning the wheels. On earth, when the engine is wound-up and released, it turns the wheels to make the car go forward on a surface. The car can also be pushed to make it go forward. In space there is no force to hold the car to a surface and, therefore, no friction. When the wound-up car is released, its wheels spin uselessly as the car floats in the air. When the car is pushed forward, it floats across the cabin - but its wheels do not turn.

When a wound-up car is placed in a circular track, it begins to move forward. The track pushes in on the car to make it turn. The car reacts to this inward push by pushing outward. Once these two forces are produced, the car sticks to the track and friction occurs. With friction, the car's wheels have traction, and their turning motion makes the car move. The car's motion on the circular track slows down as the car transfers its kinetic energy of motion to the heating up of the wheels and track.

TWENTY TOY QUESTIONS

1. In space, paddling a paddleball upward is
___as easy as paddling downward.
___impossible.
___very difficult.
___much faster than paddling downward.

2. In space, the paddleball ball has its greatest speed when it is
___farthest from the paddle.
___closest to the floor.
___hitting the paddle.
___stretched away from the paddle.

3. When a wound-up toy car is released in space, its wheels
___spin rapidly in place.
___move the car forward.
___rub against the table as the car moves.
___cause the car to turn flips.

4. In space, a toy car moving on the inside of a circular track will
___keep its speed.
___slow down.
___have non-turning wheels.
___increase its speed.

5. When a paper airplane is thrown backward in space, it
___makes a loop.
___does a banked curve.
___flies as well as it does going forward.
___tumbles.

6. When compared with earth flight, a space plane
___flies faster.
___dives more easily.
___flies a straighter path.
___is more difficult to fly.

7. When you release a ball in space, it
___falls.
___floats.
___spins.
___sticks to the cabin wall.

8. Why is it difficult to play space jacks?
___The jacks move apart.
___The ball does not bounce.
___The jacks stick together.
___The ball moves too fast.

9. What is Rat Stuff's problem as he tries to flip off a wall?
___His spring will not wind in space.
___He floats off the wall.
___His head will not bend forward.
___His legs kick forward.

10. What is the direction of Rat Stuff's motion as he leaves the wall?
___toward the ceiling
___in a backward arc
___in a forward arc
___straight out

11. To start a top with a push knob in space, you must remember to
___start the top upside down.
___hold the top down.
___push down harder on the knob.
___pull up more quickly on the knob.

12. A gyroscope's spin causes it to resist any force that would
___retilt its spin axis.
___keep it floating in space.
___move it through the cabin.
___prevent its wobbling.

13. In space an astronaut can yo-yo
___at slow speeds only.
___at fast speeds only.
___at any speed.
___when the loop around the yo-yo shaft is tight.

14. It is impossible for astronauts in space to do yo-yo tricks where the yo-yo must
___change direction.
___be thrown side-arm.
___move slowly.
___stay at the end of the string.

15. In space a wheelo can be started by
___slinging the track sideways.
___tilting the track down.
___tilting the track up.
___placing the wheel at the loop in the track.

16. The wheel stays on the wheelo track in space because of its
___spin.
___inertia.
___magnetism.
___mass.

17. When two magnetic marbles come together in space, they
___spin around each other.
___repel.
___bounce apart.
___orbit at a distance.

18. When two rings of six marbles collide in space, they
___always repel.
___can form one large ring.
___must form a figure-eight.
___can break into a long chain.

19. In space a slinky will NOT
___walk.
___carry waves.
___come together when stretched.
___vibrate when shaken.

20. When a slinky is stretched apart in space,
___it sags.
___it stays stretched out.
___its coils spread apart evenly.
___its coils collect at the ends.

TOYS IN SPACE

THE RESULTS FROM SPACE
as well as
EARTH-BASED EXPERIMENTS AND ACTIVITIES

Teacher Resource Laboratory
Goddard Space Flight Center
Code 130.3
Greenbelt, Maryland

(301) 344-8570

NASA
National Aeronautics and
Space Administration

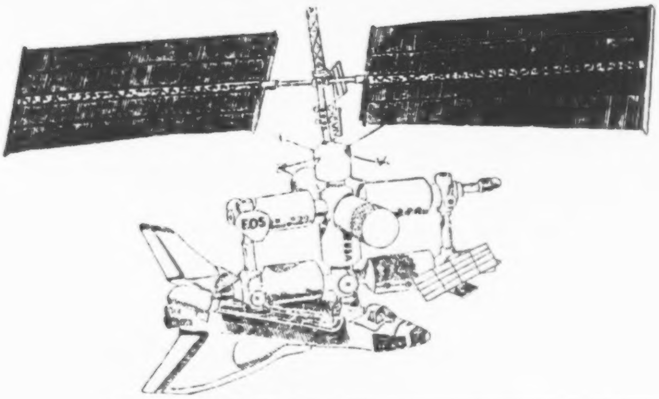
Goddard Space Flight Center
Greenbelt, Maryland 20771

ACTIVITIES

MODULE IV: **THE SPACE COLONY**

The Threshold for Exploration

From Known to Unknown
Where Shall We Locate?
Living on the Colony
What Will the Colony Be Like?
What Next?



FROM KNOWN TO UNKNOWN

Preparation/Materials
- The Colony Connection
- Review the "All You Need to Know About Space Colonies" in the Fact Book.

Math Skills
- Order of Operations
- Graphing Data

During class:

- Discuss the need for a space station or space colony in order to pursue space exploration. Include the following information:
  - The shuttle can bring us only so far in the solar system.
  - The colony serves as a home base for future voyages.
  - The colony/station rockets can be built for further travel.

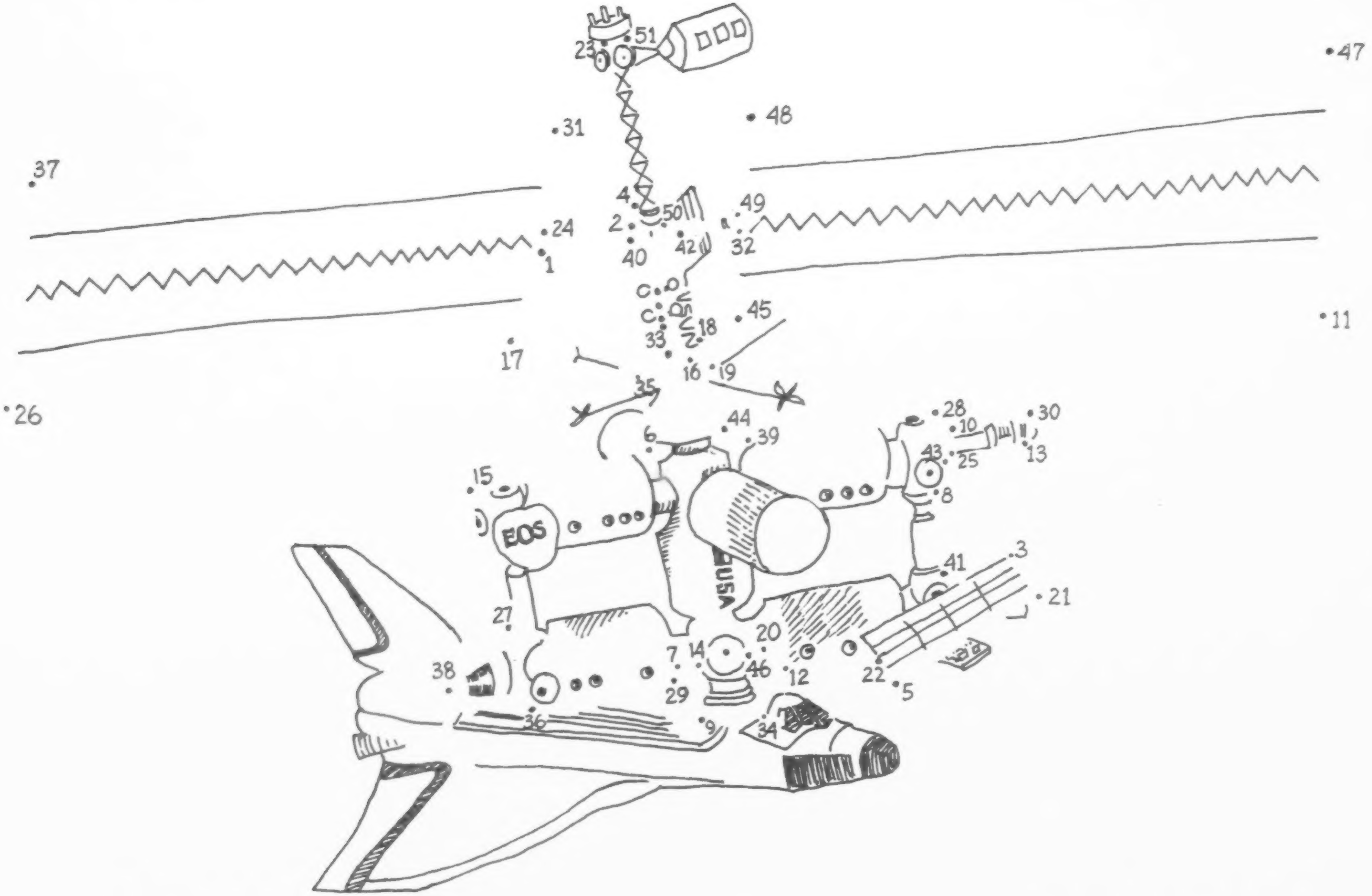
- Explain to students that they will be designing their own space colonies.

- Discuss the questions that must be resolved before a colony can be built:
  - What will be its purpose?
  - How many and what kind of people will live there?
  - Does it need to be self-sustaining?
  - What are the limitations of living in space?
  - What is its location relative to earth?
  - Should it be permanent?
  - Would you like to live on a space station?

Extensions
- Discuss similarities/differences of living in space stations to living on earth.
- Journal Entry: What philosophy should govern the space station?

The Colony Connection

Name ______________________



Regional Math Network • Harvard Graduate School of Education • Harvard University

Name ____________________

THE COLONY CONNECTION

Solve each problem, using the rules for order of operations.

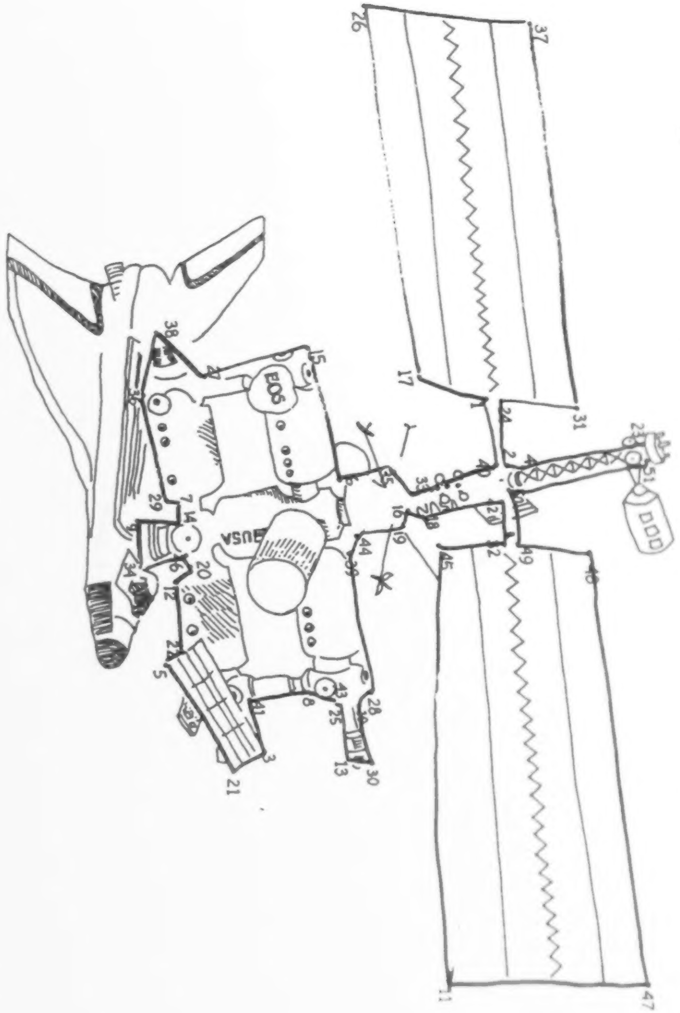
Do the problems in order from A to TT.

The solution to the problem represents the numbers you should connect on the drawing. For example, the solution to A is 23. Start with 23. The solution to B tells you the next number to which you should draw your line.

A. 1 + (11 x (8 / 4)) = 23
B. 6 + 40 / 5 - ((1 / 3) x 30) = 4
C. (13 - 3) / 5 = 2
D. 10 x 2 + 2^2 = 24
E. 3^2 x (16 / 4) - 5 = 31
F. (4 x 5) + (10 x 2) - 3 = 37
G. 8 x 6 - 26 + 4 = 26
H. 3^3 - 5 x 2 = 17
I. 12 x 3 - 7 x (6 - 1) = 1
J. 30 + (30 x (1 / 3)) = 40
K. 11 x (15 / 5) = 33
L. (1 / 3) x 75 + 10 = 35
M. 17 - 2 + 20 - 29 = 6
N. [6 + (8 / 2)] + 5 = 15
O. 32 - [(12 / 4) + 2] = 27
P. (12 x 3) + (18 / 9) = 38
Q. (4 + 2) x 7 - 6 = 36
R. 4 + (49 + 1) x 1 / 2 = 29
S. 42 / 6 + 5 - (10 x (1 / 2)) = 7
T. ((1 / 2) + (3 / 2)) x 8 - 2 = 14
U. 5^2 + 2 x 3 - (2 x 11) = 9
V. (25 + 5) x 7 - 1 = 34
W. 20 + [(3 x 8) + 2] = 46
X. (18 - 8) x 2 = 20
Y. 1 / 2 x (3 + 3 x 7) = 12
Z. 2 x (6 + 5) = 22
AA. 45 - 8 x 5 = 5
BB. (4^2 - 6) + 11 = 21
CC. 4^2 + 8 - (3 x 7) = 3
DD. (100 / 2) - 3^2 = 41
EE. 100 - (25 x 3) - 17 = 8
FF. (1 / 2) x [4 x 20] + 3 = 43
GG. 3 x 7 + (8 / 2) = 25
HH. 2^3 - 6 + 11 = 13
II. (42 / 6) x 4 + 2 = 30
JJ. 200 / 10 - 5 x 2 = 10
KK. 4 x [3 + (8 / 2)] = 28
LL. (20 / 2) x 4 - 1 = 39
MM. 32 + 16 - (2 x 2) = 44
NN. 4 + (3 x 5) = 19
OO. 6 + [(10 / 2) + 5] = 16
PP. (4 x 3) + (12 / 2) = 18
QQ. (10 - 3) x (18 / 3) = 42
RR. 6 + (13 x 2) = 32
SS. [40 + (2 x 10)] - (3 x 5) = 45
TT. 9 x 3 + 3 - 19 = 11

Regional Math Network • Harvard Graduate School of Education • Harvard University

The Colony Connection



Name ____________________

Regional Math Network • Harvard Graduate School of Education • Harvard University

Name _______________________

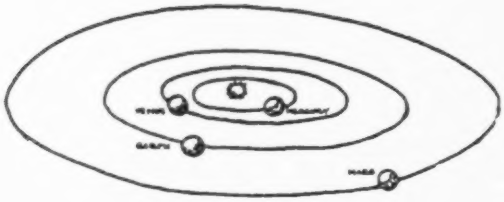
THE COLONY CONNECTION

Solve each problem, using the rules for order of operations.

Do the problems in order from A to TT.

The solution to the problem represents the numbers you should connect on the drawing. For example, the solution to A is 23. Start with 23. The solution to B tells you the next number to which you should draw your line.

A. 1 + (11 x (8 / 4)) =_____
B. 6 + 40 / 5 - ((1 / 3) x 30) =_____
C. (13 - 3) / 5 =__2__
D. 10 x 2 + 2^2 =_____
E. 3^2 x (16 / 4) - 5 =_____
F. (4 x 5) + (10 x 2) - 3 =_____
G. 8 x 6 - 26 + 4 =_____
H. 3^3 - 5 x 2 =_____
I. 12 x 3 - 7 x (6 - 1) =_____
J. 30 + (30 x (1 / 3)) =_____
K. 11 x (15 / 5) =_____
L. (1 / 3) x 75 + 10 =_____
M. 17 - 2 + 20 - 29 =_____
N. [6 + (8 / 2)] + 5 =_____
O. 32 - [(12 / 4) + 2] =_____
P. (12 x 3) + (18 / 9) =_____
Q. (4 + 2) x 7 - 6 =_____
R. 4 + (49 + 1) x 1 / 2 =_____
S. 42 / 6 + 5 - (10 x (1 / 2)) =_____
T. ((1 / 2) + (3 / 2)) x 8 - 2 =_____
U. 5^2 + 2 x 3 - (2 x 11) =_____
V. (25 ÷ 5) x 7 - 1 =_____
W. 20 + [(3 x 8) + 2] =_____
X. (18 - 8) x 2 =_____
Y. 1 / 2 x (3 + 3 x 7) =_____
Z. 2 x (6 + 5) =_____
AA. 45 - 8 x 5 =_____
BB. (4^2 - 6) + 11 =_____
CC. 4^2 + 8 - (3 x 7) =_____
DD. (100 / 2) - 3^2 =_____
EE. 100 - (25 x 3) - 17 =_____
FF. (1 / 2) x [4 x 20] + 3 =_____
GG. 3 x 7 + (8 / 2) =_____
HH. 2^3 - 6 + 11 =_____
II. (42 / 6) x 4 + 2 =_____
JJ. 200 / 10 - 5 x 2 =_____
KK. 4 x [3 + (8 / 2)] =_____
LL. (20 / 2) x 4 - 1 =_____
MM. 32 + 16 - (2 x 2) =_____
NN. 4 + (3 x 5) =_____
OO. 6 + [(10 / 2) + 5] =_____
PP. (4 x 3) + (12 / 2) =_____
QQ. (10 - 3) x (18 / 3) =_____
RR. 6 + (13 x 2) =_____
SS. [40 + (2 x 10)] - (3 x 5) =_____
TT. 9 x 3 + 3 - 19 =_____



WHERE SHALL WE LOCATE?

Preparation/Materials	Math Skills
• "Where Shall We Locate?"	• Scale Models and Scale Drawing

During class:

- Choose a location for the space colony.
  Discuss the reasons for making this choice.
- Locate the position of the space station on "Where Shall We Locate."
- Pose the following question to the students:

  -Imagine you were to telephone a friend and want to describe the position of your colony. How would you describe its location?

- Describe the location of the colony in relation to the other planets:
  - Is it among inner or outer planets?
  - What is its distance from earth?
  - Name the closest planet?
  - What is the distance to closest planet?
  - What is its distance from sun?

Extensions

- Journal Entry:
  - What do you hope for your colony?
  - How will it be like earth?
  - How will it be different?

Name: ______________________

Description of your colony's location:

Is it an inner or outer planet? ____________

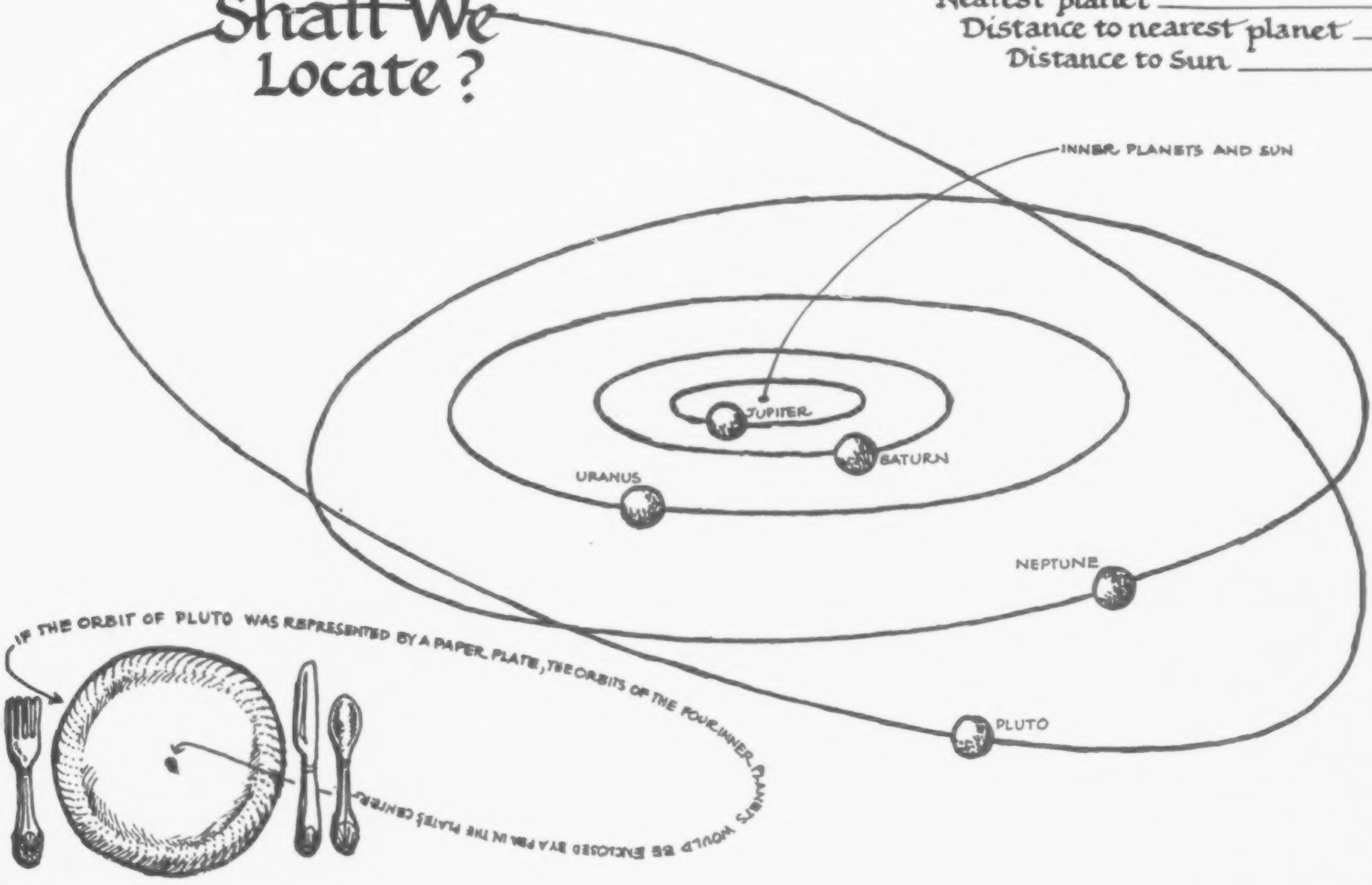
Distance from Earth ____________

Nearest planet ____________

Distance to nearest planet ____________

Distance to Sun ____________

Where Shall We Locate?



IF THE ORBIT OF PLUTO WAS REPRESENTED BY A PAPER PLATE, THE ORBITS OF THE FOUR INNER PLANETS WOULD BE ENCLOSED BY A PIN IN THE PLATE'S CENTRE.

LIVING ON THE COLONY

Preparation/Materials	**Math Skills**
• Solar Cells	• Estimation in Computation Measurement • Area

During class:

- Discuss the features that must be planned for living on a colony:
  - Is there gravity? How will it be produced?
  - Is there air? How will it be created?
  - What about energy?
  - What percent of space should be allocated for various functions:
    - living
    - exercise and recreation
    - agriculture
    - technical laboratories

- Focus on the energy issue. Discuss that energy will be obtained from the sun, using solar panels.
  The panels collect and transform solar energy to electrical energy.

- Point out to the students that the amount of energy needed by the colony must be estimated, so that an appropriate number of solar panels can be provided.

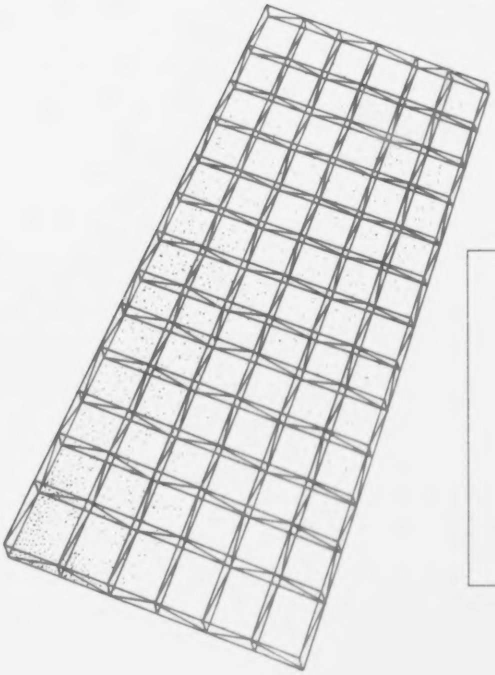
- Explain that the students must estimate the number of solar panels needed to meet the energy needs of the colony on a daily basis.
  - First, students must project the number of watts used per month for a family of 4.
  - Next, students calculate the approximate number of watts used per day by a family.
  - Finally, students should project the needs for the entire colony.

Extensions

- Solar Cells
- Explore the other features of living on the colony: gravity, "air," use of space.

Name ______________________

SOLAR CELLS....
POWER FROM THE SUN



SOLAR CELLS CONVERT THE ENERGY OF
SUNLIGHT DIRECTLY INTO
ELECTRICAL ENERGY

FOR A CERTAIN SOLAR CELL,
AN AREA OF 1 SQUARE INCH
RECEIVES IN DIRECT OVERHEAD SUNLIGHT
ABOUT 0.65 WATT OF POWER

1. Approximately how many solar cells would be needed to generate the light of a 60-watt light bulb?

   What are the possible dimensions of a rectangular solar cell surface for the 60-watt light bulb?

2. A typical home, with a family of 4, used 124 kilowatt hours during June (One Kilowatt is one thousand watts).

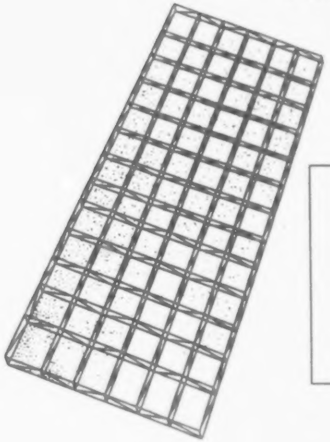
   How many inches of solar cells are needed to generate this power?

   What are the possible dimensions of the solar cell surface for 124 kilowatts?

3. Estimate your home's energy requirements for a year.
   How large a solar panel would you need to generate the energy needed?

Name ______________________

SOLAR CELLS....
POWER FROM THE SUN



SOLAR CELLS CONVERT THE ENERGY OF SUNLIGHT DIRECTLY INTO ELECTRICAL ENERGY

FOR A CERTAIN SOLAR CELL, AN AREA OF 1 SQUARE INCH RECEIVES IN DIRECT OVERHEAD SUNLIGHT ABOUT 0.65 WATT OF POWER

1. Approximately how many solar cells would be needed to generate the light of a 60-watt light bulb? 92 cells

   What are the possible dimensions of a rectangular solar cell surface for the 60-watt light bulb? perimeter must be 4 × 92 inches

2. A typical home, with a family of 4, used 124 kilowatt hours during June (One Kilowatt is one thousand watts).

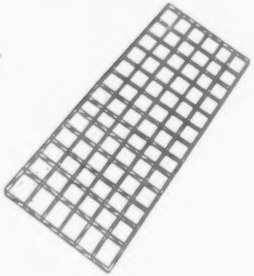
   How many inches of solar cells are needed to generate this power? ≈ 191,000 sq. in.

   What are the possible dimensions of the solar cell surface for 124 kilowatts?
   Perimeter ≈ 763,000 in.

3. Estimate your home's energy requirements for a year.
   How large a solar panel would you need to generate the energy needed?

Name ______________________

SOLAR CELLS
A SOURCE OF ENERGY



Solar cells are made in various shapes to utilize the greatest amount of lateral area.

A certain circular solar cell, with a radius of r, will produce 5 watts.

1. If the radius were 10 inches to produce 5 watts, what output would be produced if the radius were 20 inches?
   If $r = 10$, $A = \pi(10^2) \approx 100\pi$
   If $r = 20$, $A = \pi(20^2) = 400\pi$, there output = 20 watts

   Would the output be doubled? Why? Why not?
   No, doubling the radius quadruples the area.

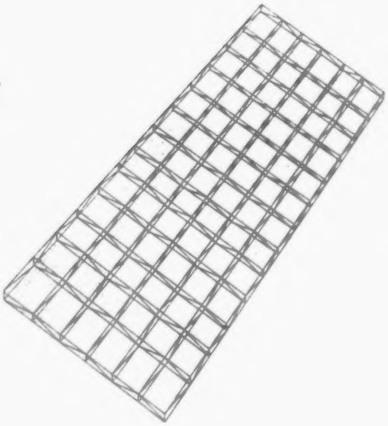
   How many times greater would the output be if the radius were 100 inches?
   100 times bigger

2. Find the dimensions of a square solar cell which would have the same output as a circular cell of radius 10 inches.
   s = length of sides in inches
   $s^2 \approx 100\pi$
   $s^2 \approx 100(3)$
   $s^2 = 300$ $s = \sqrt{300} \approx 17$ inches.

3. Find the dimensions of a solar cell shaped as an equilateral triangle which would give the same output as a circular cell of radius 10 inches.
   $A_{\odot} = A_{\Delta}$
   $300 = \frac{1}{2} \cdot b \cdot h$ $300 = \frac{1}{2} \cdot b \cdot \left(\frac{\sqrt{3}}{2} b\right)$ $\frac{1200}{\sqrt{3}} = b^2$ $600 \approx b^2$ $25 = b$
   (note: $h = \frac{\sqrt{3}}{2} b$ in a 30°-60°-90° triangle)

Name ______________________

SOLAR CELLS
A SOURCE OF ENERGY



Solar cells are made in various shapes to utilize the greatest amount of lateral area.

A certain circular solar cell, with a radius of r, will produce 5 watts.

1. If the radius were 10 inches to produce 5 watts, what output would be produced if the radius were 20 inches?

   Would the output be doubled? Why? Why not?

   How many times greater would the output be if the radius were 100 inches?

2. Find the dimensions of a square solar cell which would have the same output as a circular cell of radius 10 inches.

3. Find the dimensions of a solar cell shaped as an equilateral triangle which would give the same output as a circular cell of radius 10 inches.

WHAT WILL THE COLONY BE LIKE?

Preparation/Materials

- Build as a sample some geometric solids using panels and elastics
- Duplicate copies of Geometric panels on construction paper
- "My Space Colony"
- Scissors
- Elastics

Math Skills

- Measurement : Surface Area
  : Volume
- Scale Models + Scale Drawing
- Spatial Problem Solving

During Class:

- Group the students into small teams.
  Each team will design and build their own space station using geometric solids.

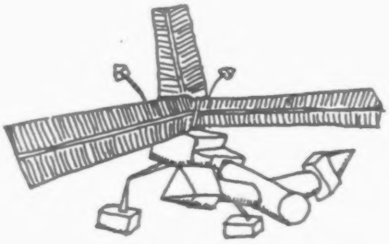
- The space station will be designed as a series of sections, which will be called "pods." Each "pod" will be a simple geometric solid made from triangular or square panels and elastics.

  Show one Pod, defining "face," "edge," and "vertex."

  The pods will be attached together to form various configurations of a larger space colony.

- Ask the students to design a configuration for the space colony, using the solids, considering:

  - the purpose for each space
  - the ease of building the station in space
  - the total surface area exposed to space
  - the amount of "inside" space

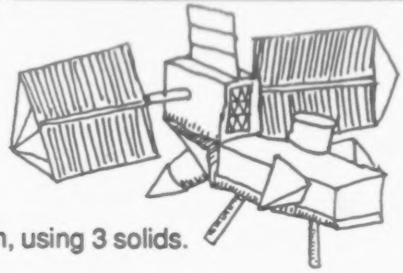


Extension

- Ask students to determine a technique to describe or represent their configuration on a two dimensional drawing, a "blueprint" for the configuration.
- Write a rationale for the station and its design relative to its purpose and philosophy.
- "A Cubic Colony"

Name ____________________

MY SPACE COLONY



1. Make a model of the initial section of your space station, using 3 solids. Describe the section:
   a. What solids did you use? How did you join them together?
   b. Total number of faces of the exterior:
   c. Total number of edges of the exterior:

2. Determine the dimensions of your initial "pod"
   a. Total lengths of edges (the length of "structural beams"):
   b. Surface area:
   c. Volume (in terms of the number of 1" cubes that would fit in it):

3. Make three pods exactly like those in your initial section of the space station. Make a new solid with the maximum number of faces on its exterior.
   Describe it.

4. Choose three more pods like the original one. Make a new solid with the minimum number of faces on its exterior.
   Describe it.

5. Compare the volume and surface area of the 3 structures you made:

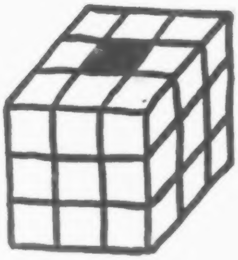
Section	Approximate Surface Area	Approximate Volume in cubic inches
Original Structure		
Structure with maximum exterior faces		
Structure with minimum exterior faces		

Name ______________________

A CUBIC COLONY

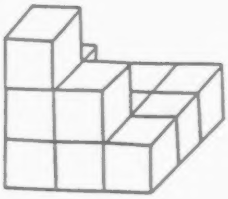
The Cubic Colony is a space station built only with cubes.

Each space station has a set of plans. The plans show the base of the station, a view of the station from the front, and a view of the station from the right side.

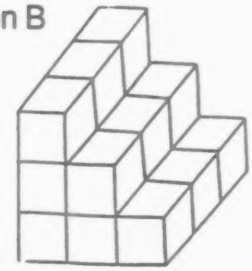


Match each station with its plans.

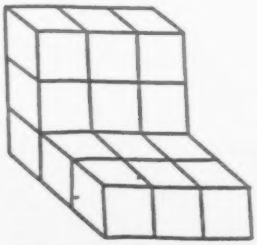
Station A



Station B



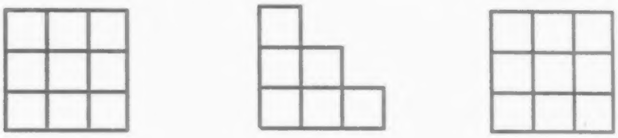
Station C



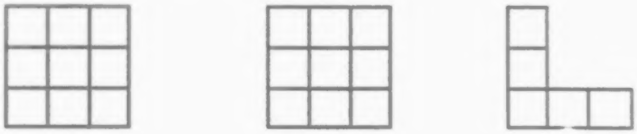
Plans

Base Front Right View

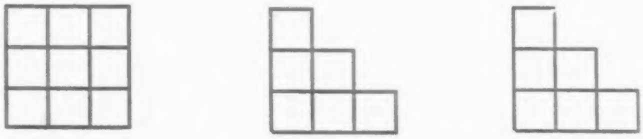
Plan A: STATION B



Plan B: STATION C

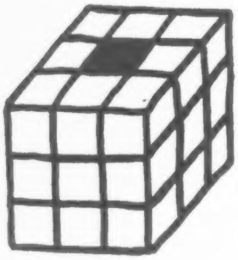


Plan C: STATION A



Name ______________________

A CUBIC COLONY

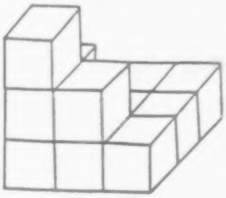


The Cubic Colony is a space station built only with cubes.

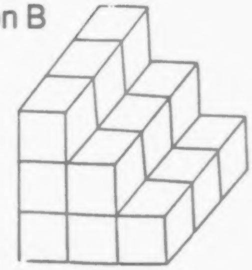
Each space station has a set of plans. The plans show the base of the station, a view of the station from the front, and a view of the station from the right side.

Match each station with its plans.

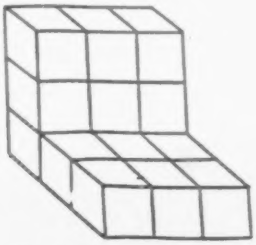
Station A



Station B



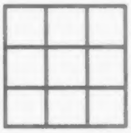
Station C

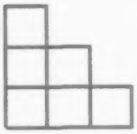


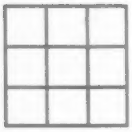
Plans

Base Front Right View

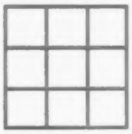
Plan A:

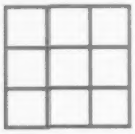


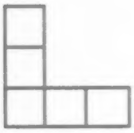




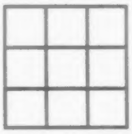
Plan B:

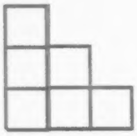


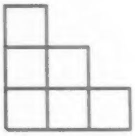




Plan C:







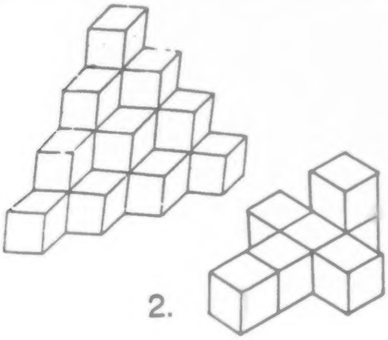
MORE CUBIC COLONIES

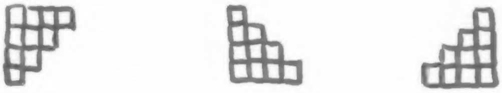
Draw the floor plans for these colonies.

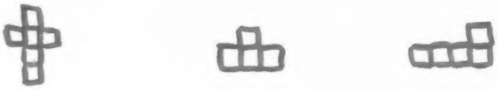
Base Front Right View

1.

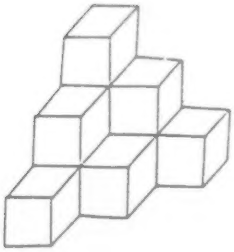
2.

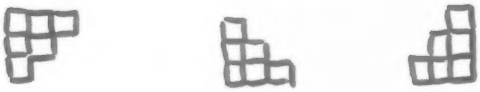






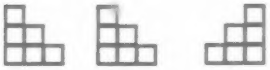
3.



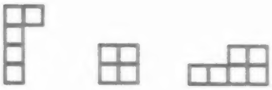


Using these views, build the colonies.

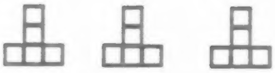
4. a.



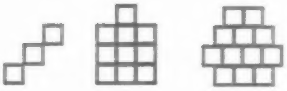
b.



c.



d.



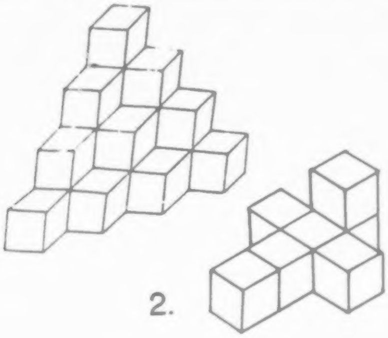
Name ____________________

MORE CUBIC COLONIES

Draw the floor plans for these colonies.

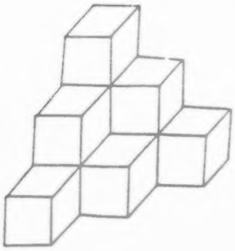
Base Front Right View

1.



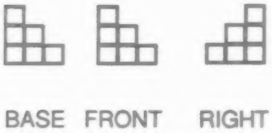
2.

3.

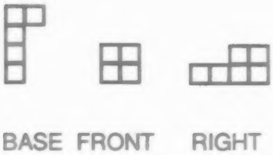


Using these views, build the colonies.

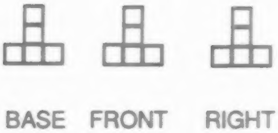
4. a.



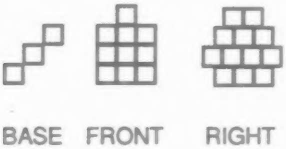
b.



c.



d.



WHAT'S NEXT?

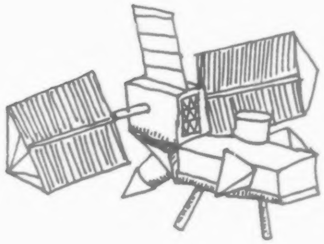
Preparation/Materials	**Math Skills**
• Build a sample space station using cubes • Draw blueprints for a sample space station • "Various Space Stations" • Cubes • Graph Paper	• Geometry • Spatial Visualization

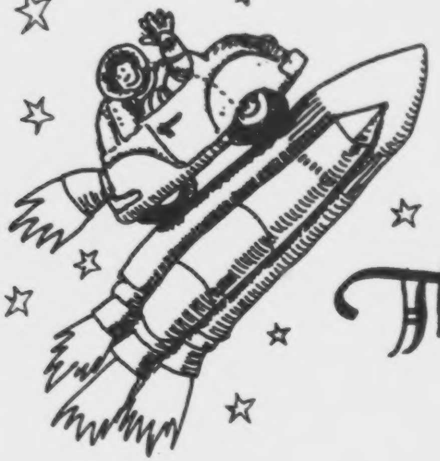
During class:

- Discuss the following questions about what the space station would be like after one year:

  - What did you learn?
  - How many babies were born?
  - How many people came?...left?
  - What problems did you face and how did you solve them?
  - Have people found it too difficult to live there?
  - Would you stay on for another year?...ten years?

- Discuss whether we have found any life in our travels.
  - If there is no life in our solar system, what next?

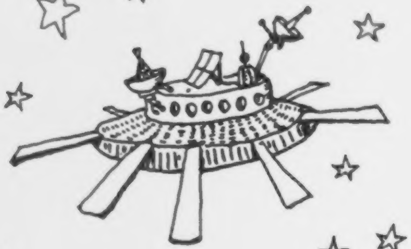




This is to certify that

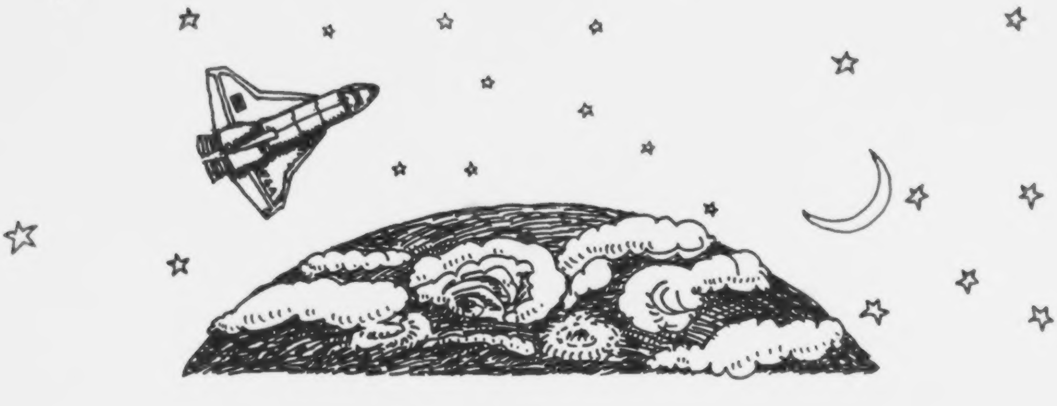
____

is recognized as
an official space colonist.



Regional Math Network • Harvard Graduate School of Education • Harvard University

math space mission



Bibliography

MATH/SPACE MISSION

BIBLIOGRAPHY OF RESOURCES

Our Solar System
- Readings
- Recreational Readings
- Films and Media
- Posters
- Computer Software
- Magazines

Space Exploration
- Readings
- Recreational Readings
- Films and Media

Space Colonies
- Readings

Math and Science Extensions

Community Resources

Selected Order Forms

Our Solar System

Readings:

A HISTORY OF ASTRONOMY FROM THALES TO KEPLER, J.L.E. Dryer, New York: Dover
Astronomical ideas from ancient Egyptians to Kepler.

ASTRONOMY, Richard Whittingham, Illinois: Hubbard Press, 1971.
Discusses the moon, planets, sun, stars, asteroids, galaxies. Excellent charts, diagrams for reference work. Also discusses instruments and techniques of observing and recording celestial phenomena.

BLACK HOLES AND OTHER SECRETS OF THE UNIVERSE, Christoper Lampton, New York: Franklin Watts, 1980.
Discusses black holes, quasars, pulsars, red giants, white dwarfs.

SPACE BOOK FOR YOUNG PEOPLE, Homer E. Newell, New York: McGraw-Hill Book Co., 1968.
Excellent resource for teachers and some students. Includes not only discussion of planets, comets, asteroids, etc. but also explains big numbers (exponential notation) and small numbers, the ellipse, effects of gravity, comparing volumes and sizes.

SPACE SHOTS: AN ALBUM OF THE UNIVERSE, Fred Hapgood, New York: Time Books, 1979.
Beautiful full page photographs of the planets, galaxies, supernovae, etc., with text.

SKY ABOVE AND WORLDS BEYOND, Judith Herbst, New York: Atheneum, 1983.
Tour of the universe, planets, comets, meteors, etc. Excellent chapters on how ancient people tracked stars and searched for life in space. Informal style and humor make it pleasantly readable for students and teachers. Separate chapters could be used for research or reports.

THE AMAZING UNIVERSE, Herbert Friedman, Washington, D.C.: National Geographic Society.
200 illustrations. Topics discussed include planets, stars, galaxies, black holes, cosmic order, search for life. Advanced reading level.

THE COSMIC CONNECTION, Carl Sagan, New York: Dell, 1975.
Astronomer Sagan writes about such amazing things as preparing the way for contact with intelligent beings on planets of other stars, space vehicle exploration of the solar system, the search for life on Mars, and duplicating the steps that led to the origin of life on Earth 4 billion years ago.

THE DISCOVERY OF OUR GALAXY, Charles A. Whitney, New York: Alfred A. Knopf, 1971.
Relates discoveries of great astronomers from ancient times to present day. Good resource material for teacher or student report. Advanced reading level.

THE SILVER BURDETT COLOR LIBRARY: SPACE, Ian Ridpath, New York: MacMillan Publishers, 1983.
Excellent large photographs; topics include sun, stars, moon, planets, galaxies, observatories, rockets, satellites, uses of space.

THE SKY OBSERVER'S GUIDE, R. Newton Mayall, Margaret Mayall, Jerome Wyckoff, New York: Golden Press, 1971.
Information about planets, stars, comets, tips on observing the heavens, auroras. Excellent resource.

THE UNIVERSE, David Bergamini, New York: Time-Life Books, 1970.
Chapters include Early Explorers of the Heavens, Mighty Instruments to Probe the Skies, Planets, Asteroids, and Comets, The Nuclear Furnace of the Sun, What our Galaxy is Made Of, The Birth, Life and Death of Stars, The Cosmos Beyond the Milky Way.

THE YOUNG SCIENTIST BOOK OF STARS AND PLANETS, Christopher Maynard, Saint Paul, Minnesota: EMC Corp.
Many photographs, diagrams, charts, introduction to solar system, suggested experiments. Excellent resource for teacher and students. Reading level Grade 6.

ELEMENTARY SCHOOL AEROSPACE ACTIVITIES. A RESOURCE FOR TEACHERS, NASA, 1977.
Provides an approximate chronological development of the story of man and flight, with an emphasis on flight into space. Specific activities are described for students of particular ages to introduce them experientially to basic concepts.

THE SHAPES OF TOMORROW, NASA, 1967.
Focuses on use of geometric concepts as they apply to space and space exploration issues (secondary focus).

WHAT'S UP THERE, NASA, 1964.
A source book on space-oriented mathematics (grades 5-8).

SUN, EARTH, AND MAN, NASA, 1982.
Reports on the quest of knowledge of Sun-Earth Relationships.

Duplicating masters and transparencies:

THE SOLAR SYSTEM AND SPACE TRAVEL FOR GRADES 5 TO 9, St. Louis, Missouri: Milliken Publishing Co., 1970.

Recreational reading:

BETWEEN PLANETS, Robert A. Heinlein, New York: Ace, 1951.
Robert Heinlein shows us how it feels to be living far in the future - to be a citizen of an Interplanetary Federation. He depicts what might happen under such an organization if it were to disregard the rights of the individual.

FANTASTIC VOYAGE, Isaac Asimov, New York: Bantam, 1966.
A James Bond type story about a medical team that travels in a miniaturized spaceship through the blood stream of a famous scientist in order to dissolve a blood clot threatening the scientist's life.

I, ROBOT, Isaac Asimov, New York: Signet, 1950.
A collection of short stories about robots. Asimov invented the "Three Laws of Robotics" and uses them in these stories.

OTHER WORLDS, Carl Sagan, New York: Bantam, 1975.
Is there life out there? Our first steps into space have already shown us other worlds stranger than anything in science fiction. This book presents some of Sagan's ideas on the galactic telephone and the cosmic clock, whether there are big beasts on Mars, the speed of light as a barrier to space travel, and fringe science such as UFOs, astrology, and "chariots of the gods."

ROCKET SHIP GALILEO, Robert Heinlein, New York: Ace, 1947.
A thrilling story of three boys who accompany a scientist on the first piloted rocketship flight to the moon. The time is several years from now. The action is based on scientific fact, and much of it may come true before long. The illustrations have been carefully worked out under Heinlein's supervision, and they are as accurate as it is possible for "projected illustrations" to be. Heinlein is in the top rank of science fiction writers, and his unusual stories for adults have attracted much attention. This, one of his many books for children, is even more fascinating than the stories of Jules Verne.

Our Solar System

Films and media:

The Universe, 30 minute videocassette in color available in VHS or BETAMAX, narrated by William Shatner. This film uses actual NASA photographs and animation to explore our solar system and its planets, to travel through the Milky Way Galaxy into deep space, to discuss theories on the evolution of the universe, pulsars, quasars, black holes, solar wind and super novae. The film also gives a dynamic presentation of the sun as a powerful nuclear furnace.

Previewer's Comment:

Universe offers a dramatic way to capture the excitement of space. Students will benefit from a second showing in the science class where the science teacher can provide (student)s with definitions of some terms and explanations of some concepts. Students may be assigned research projects regarding this material from the science teacher.

Available From:
Finley-Holiday Film Corp.
PO Box 619
Whittier, CA 90608
$39.95 plus tax and shipping charges.

Great Space Race, a television series shown on public television; 4 one hour programs. Part I: Payload in the Sky, Part II: Unlocking the Universe, Part III: The Earth Below, Part IV: The Next Civilization. Part II: Unlocking the Universe is of particuliar interest. It is a one hour program describing our solar system and space phenomena such as super novae, black holes, white holes, Red Giants, worm holes and dark matter.

Previewer's Comment:

This is a very exciting presentation. It is more than most adults can absorb in one sitting but the visual presentation is so dramatic that it is very stimulating. Viewer's Guide is available which gives a brief summary of facts, theories, and issues for consideration. A Space Technology Time Line is included. This series has been shown on Channels 2 and 11.

Available From:
Pacific Productions
Suite 425
Washington, D.C.

Space Exploration

Readings:

THE SPACE SHUTTLE OPERATOR'S MANUAL, Kerry Mark Joels, Gregory P. Kennedy, New York: Ballantine Books, 1982.
An excellent resource in which the reader takes the role of shuttle pilot. All aspects of the flight are realistically described.

ALBUM OF SPACE FLIGHT, Tom McGowen, Chicago: Rand McNally and Co., 1983.
Excellent illustrations, one-page descriptions.

ENTERING SPACE: AN ASTRONAUT'S ODYSSEY, Joseph P. Allen, Tokyo: Stewart, Tabori, and Chang, Dai Nippon Printing Co., Ltd.
Beautiful photographs and description by astronaut Joseph Allen of what it is like to circle the earth at 17,000 mph.

FINDING OUT ABOUT OUR EARTH, SUN, MOON AND PLANETS, ROCKETS AND SPACEFLIGHT, Washington, D.C.: NASA
Designed for young readers but includes excellent diagrams and drawings to answer many questions children ask. For example, how rockets work, why astronauts wear space suits, etc.

HOW DO YOU GO TO THE BATHROOM IN SPACE?, William R. Pogue, New York: Tom Doherty Associates, 1985.
Excellent resource, easy reading, question and answer format, highly recommended. Author William Pogue is an American astronaut who spent 84 days in space.

MY FIRST BOOK OF SPACE, Rosanna Hansen, Robert A. Bell, New York: Simon and Schuster, Inc., 1982.
Excellent photographs, paintings, and diagrams developed in conjunction with NASA. Includes discussion of planets, asteroids, comets, meteoroids. Large print.

NATIONAL GEOGRAPHIC, Vol. 164, No. 3, September 1983, "Satellites that Serve Us" p.281 and Spacelab, p. 301.
Vol. 163, No. 6, June 1983, The Once and Future Universe, p. 704.

ORBITING THE SUN: PLANETS AND SATELLITES OF THE SOLAR SYSTEM, Fred L. Whipple, Cambridge, MA: Harvard University Press.
Teachers' Resource book. Chapters include: The Moon's Influence on the Earth, Weights and Measures, How the System Holds Together, and discussions of each planet.

OUT OF THE CRADLE: EXPLORING THE FRONTIERS BEYOND EARTH, William K. Hartman, Ron Miller, Pamela Lee, New York: Workman Publishing, 1984.
Color paintings, photographs and text.

Space Exploration

THE SPACE PROGRAM: PROVIDING DOWN TO EARTH BENEFITS, Office of Government Relations, Space Transportation and Systems Group, Rockwell International, Downey, CA 90241, Pub 2459-F Rev 10-83.
Report that provides an overview of the space program including space applications, economic benefits, shuttle missions, and shuttle applications. Short paragraphs, outline form, graphs, charts, photographs.

THE SPACE PROGRAM QUIZ AND FACT BOOK, Timothy B. Benford and Brian Wilkes, New York: Harper and Row, 1985.
An interesting collection of little-known details, odd facts, anecdotes, vignettes and superlatives served up in an entertaining and educational format. Introduction by Frank Borman.

SPACE SHOTS, SHUTTLES AND SATELLITES, Melvin Berger, New York: G.P. Putnam's Sons, 1983.
Includes chapter on becoming an astronaut, countdown (steps to launching and touchdown of test space flight of Columbia 1981), scientific, weather, and military satellites.

SPACE SHUTTLE, Robin Kerrod, New York: Gallery Books, 1985.
Beautiful photographs with some text. Highly recommended. Special edition for Smithsonian Institute of Washington DC.

MODEL ROCKETS, Estes, 33 North Main St., Chambersburg, PA 17201
Kits for making working rockets.

AVIATION AND SPACE EDUCATION, FOLDER GAMES FOR THE CLASSROOM, Humanities Limited, Atlanta, Georgia.
Educational activities structured around aviation and space topics currently in the news.

Space Exploration

Recreational reading:

SPACE CADET, Robert A. Heinlein, New York: Ace, 1948.
The year is 2075. New cadets are being sworn in at the rocketship training school at Terra Base, Colorado. The commandant raises his hand: "Repeat after me: 'Of my own free will without reservation........I swear to uphod the peace of the Solar System... To defend the constitution of the Solar Federation." So Matt and Tex from Terra, Oscar from Venus, Pierre from one of Jupiter's moons, and others put on their uniforms and start their training and their strange adventures in the Solar Patrol. Exciting, strange, "weird", yet as realistic and as scientific as a story projected into the future can be. This story gives us some idea of what interplanetary communication may mean.

STRANGER IN A STRANGE LAND, Robert A. Heinlein, New York: Berkeley, 1961.
This is the story of Valentine Michael Smith, born and educated on Mars, who arrives on our planet as a superhuman. He shocks the morals of Western culture by attempting to set up a strange and fascinating discipline on Earth.

THE MARTIAN CHRONICLES, Ray Bradbury, New York: Bantam, 1958.
This book is a diary account linking several short stories about Earth's attempts to land rockets on Mars.

THE WHITE MOUNTAIN, John Christopher, New York: Macmillan, 1969.
In the distant future, Earthmen are ruled by an alien race that controls peoples' minds through skull caps implanted at the age of fourteen. Three boys escape before they are capped and make a perilous journey to the White Mountains, where there is a band of free men fighting aliens.

Films and media:

Jet Propulsion Laboratory: Slide and cassettes (Specific description and order form at end of Bibliography)

SPACE SHUTTLE, 40 slides with audio cassette.

STS: POST FLIGHT PRESS CONFERENCE (1982), (17 minutes)
Available in 16mm and video cassette (NASA Goddard Flight Center).
Contains highlights of the 3rd flight of the Space Shuttle Columbia with narration by the crew, Jack Lousman and Gordon Fullerton, recorded at a live press conference.

Previewer's Comments:

The film moves quickly through the various aspects of the flight (launch, inflight, landing) in a simple yet interesting manner. One of the high-points of the film is a description of the effects of zero-gravity on the astronauts. An excellent stimulus for classroom discussion.

Space Colonies

51D: POST FLIGHT PRESS CONFERENCE (1985) - TIME
Available in 16mm film and video cassette (NASA Goddard Flight Center).

Readings:

OUT OF THE CRADLE: EXPLORING THE FRONTIERS BEYOND EARTH, William Hartmann, Ron Miller, Pamela Lee, New York: Workman Publishing, 1984.
Futuristic look into new societies, space shuttles, space cities, lunar industries, such as oxygen production, mining, robot probes.

AVIATION & SPACE EDUCATION, FOLDER GAMES FOR THE CLASSROOM, Humanities Limited, Atlanta, GA
Resources and classroom projects that can turn the classroom into a space lab.

Math and Science Extensions

POWERS OF TEN, Philip Morrison, Phylis Morrison, New York: Scientific American Books, Inc., 1982.
A fascinating film in which the viewer "zooms away" from earth in steps equal to Powers of Ten. The film demonstrates the effect of increasing multiples of tens.

PUZZLES FROM OTHER WORLDS, Martin Gardner.
37 science-fiction puzzles involving logic, wordplay, palindromes, geometry, probability, magic numbers.
No. 101366 Geyer Instructional AIDS Co. Inc. P.O. Box 10060, Fort Wayne, Indiana, 46850.

PUZZLES IN SPACE, David Stonerod, Palo Alto, California: Stokes Publishing Co.,1982.
Provides patterns and step-by-step guide to building models including tetrahedrons, hexahedrons, cubes and pyramids. Includes many questions asked about faces, vertices, volumes, etc.

SPACES: SOLVING PROBLEMS OF ACCESS TO CAREERS IN ENGINEERING AND SCIENCE, Dale Seymour Publications, P.O. Box 10888, Palo Alto, CA 94303
Spiral bound paper cover.

THE WHOLE COSMOS: A CATALOG OF SCIENCE ACTIVITIES, Joe Abruscato and Jack Hassard, Glenview, Illinois: Scott Foresman and Co., 1977.
Excellent resource for science activities, puzzles and games, science bibliographies of various lengths - provides actual activities also stimulates ideas for related activities - highly recommended, not only for this unit but for any classroom integrating many disciplines.

WOMEN IN MATHEMATICS, Lynn Olsen.
No. 100660, Geyer Instructional Aids Co., Inc. P.O. Box 10060, Fort Wayne, Indiana, 46850.

COSMOS, a television series shown on public television hosted by Carl Sagan and based on his discussions about aspects of our solar system. Contact your local educational television station.

The following slides and cassettes are available from the Jet Propulsion laboratories:

VOYAGER 2 ENCOUNTERS SATURN, 40 slides with audio cassette.

VOYAGER 2 ENCOUNTERS JUPITER, 40 slides with audio cassette.

VIKING-MARS LANDING, 40 slides with audio cassette.

VIKING MISSION TO MARS, 40 slides.

VOYAGER MISSION TO JUPITER, 40 slides.

MARINER 9 MISSION, 40 slides.

EARTH, 40 slides.

VOYAGER MISSION TO SATURN, 40 slides.

Posters:

NASA: Ten Years of Planetary Exploration ISBN 033 000 00861-9
Comparing the Planets 033 000 0744-2
International Cometary Explorer WAL 118/9-85

Creative Publications: Earth shapes, the earth projected on a variety of geometric solids

Museum of Science (Boston), The Solar System

Computer software:

MacStronomy, a program for the Macintosh involving interactive astronomy experiences.

Magazines:

Odyssey, a monthly magazine whose subject is space, and space exploration.
1027 N. Seventh St., Milwaukee, WI 53233

JPL ORDER FORM

FILL OUT THIS FORM WHEN ORDERING ITEMS FROM EDUCATIONAL OUTREACH AND TURN IT IN TO THE JPL CURRICULUM DEVELOPMENT CENTER OR MAIL TO:

EDUCATION OUTREACH
JET PROPULSION LABORATORY
4800 OAK GROVE DRIVE
MAIL STOP 520-100
PASADENA, CA 91109

Quantity desired	Cost	Title
	$ 20.00	MICROGRAVITY
	$ 4.00	COMPUTERIZED SEARCH CATALOG FOR NASA WRITTEN MATERIALS AND VHS VIDEO TAPES. (SPECIFY APPLE OR IBM) APPLE__________ IBM__________
	$ 4.00	THE "GO" PROGRAM (APPLE ONLY)
	$ 4.50	UNDERSTANDING COMPUTERS

NAME______________________________ PHONE______________

MAILING ADDRESS____

CITY____________________ STATE____________ ZIP____________

TOTAL NUMBER OF ITEMS ORDERED________________________________

AMOUNT OF CHECK OR MONEY ORDER $________________________________

Community Resources

MUSEUM OF SCIENCE	Science Park Boston, MA	General exhibits as well as special programs in science and space are a part of the ongoing offerings of the Museum. Contact person: Matt Stein
HAYDEN PLANETARIUM	Museum of Science Science Park Boston, MA	The Museum of Science offers a planetary show which can be planned for school groups; free shows on Friday evenings. Contact person: Matt Stein
YOUNG ASTRONAUT PROGRAM	Museum of Science Science Park Boston, MA	A program which offers monthly newsletter, with specific bulletins, classroom activities and experiments, and laboratory suggestions.
MIT	Memorial Drive Cambridge, MA	Two days are scheduled each year for open house visits for MIT alumni and the community at large when special displays and programs are provided. Of special interest is the Department of Aeronautical and Astrological Research which is involved in experiments sent on the shuttle including man's productivity in zero gravity, and building structures in space. Contact person: Dr. David Akin Director of LOOP, (Laboratory for Orbital Operations Programs).
SMITHSONIAN ASTROPHYSICAL OBSERVATORY	Pinnacle Road Harvard, MA 456-3395	Privately funded group engaged in "listening" activities for research into outer space. Contact person: Skip Schwartz

PARENTS OF STUDENTS IN THE SCHOOL COMMUNITY	Parents may be invited to contribute to the class by coming in to discuss certain occupations. Specific help may be sought from architects, space scientists, engineers, draftsmen, hobby shop owners, etc. Further information might be gained through interviews conducted by students with local professionals.
PROFESSIONALS FROM COMMUNITY BUSINESSES INVOLVED IN ACTIVITIES RELATED TO SPACE EXPLORATIONS	Professionals doing work with space related projects may be called in to address classes and to serve on panels. Their workplaces might serve as field trip sites. Some local companies currently involved in space related projects include: GTE ARTHUR D. LITTLE RAYTHEON HONEYWELL DRAPER LABS MITRE

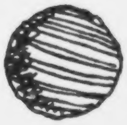
These resources apply to Greater Boston / New England area. Similar resources are available in communities around the nation.

Since some students take trips to Florida and Wahington, they should be encouraged to visit:

Kennedy Space Center in Cape Canaveral, Florida
Smithsonian Aerospace Museum, Washington, D.C.

math space mission

FACT BOOK



Regional Math Network • Harvard Graduate School of Education • Harvard University

FACT BOOK
Contents

Page

I. **Solar System Data**.. 3
- All You Need to Know About the Solar System for This Module 4
- Typical Student Questions 11
- Solar System: Planet Deck 13
- The Planets: Summary of Facts 14
- Distances Between Planets 17

II. **Shuttle System Data**.. 31
- All You Need to Know About the Shuttle System for This Module 32
- Typical Student Questions 38
- Components of the Shuttle System 39
- Space Shuttle: From Launch to Landing 43
- Stages of Shuttle Mission 45
- Types of Missions 51
- History of Manned Space Missions 55

III. **Space Colonies Data**.. 59
- All You Need to Know About Space Colonies for this Module 60

IV. **Mathematical Facts**.. 63
- Measurement Trivia 64
- Useful Formulae 66
- Mathematical Conversions of Measuring Units 68
- How to Round 69
- Calculating using Rounded Numerals 70

Editor's Notes

All numerical figures used in both the Solar System and Shuttle Modules are "nominal", rather than exact ones.

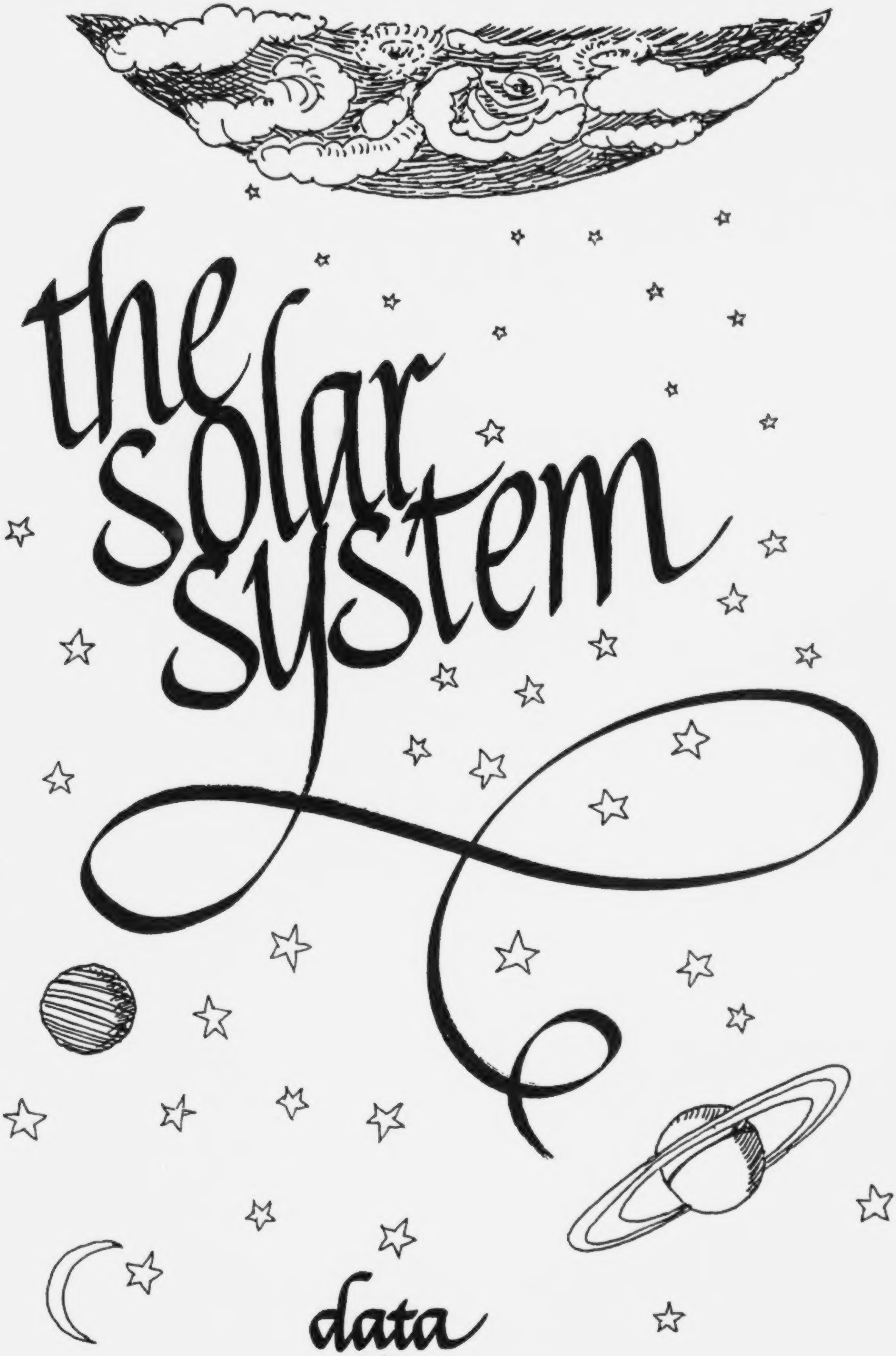
The distances and sizes of our planets are always changing. Most numbers represent quantities at a specific point in time. As the time changes, so might the numbers involved.

The data for the Shuttle Module varies with each shuttle mission and its particular goals. Data presented represents a typical shuttle mission.

The data used was primarily taken from: The Solar System, Museum of Science (Boston) and NASA Publications.

208

the solar system

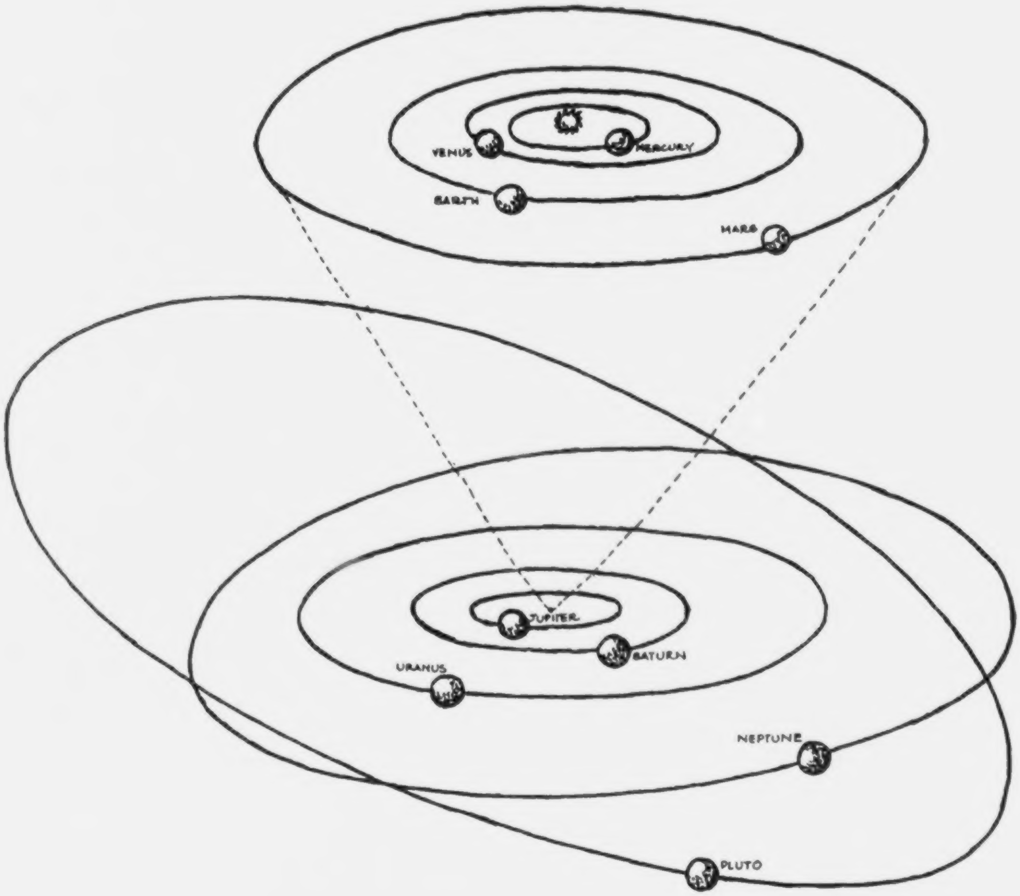


data

Fact Book
3

Regional Math Network • Harvard Graduate School of Education • Harvard University

OUR SOLAR SYSTEM
BACKGROUND INFORMATION
(ALL YOU NEED TO KNOW FOR THIS MODULE)



Our sun is a medium sized star in our galaxy which is called the Milky Way galaxy. It is thought that the Milky Way is one of a hundred billion other galaxies in our universe. There are millions of different sized stars from dwarfs to red giants in the Milky Way. Because of the immense number of stars in the universe, several hundred trillion, mathematics indicates that there is a good probability of other intelligent life in our galaxy (perhaps 15 such planets). Our sun will continue to shine and send us solar energy for another 4 billion years. At that time it is predicted that the sun will have used up all its sources of energy (hydrogen and other gases) and will no longer support life on our planet

Revolving around the sun are the nine planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. Each planet travels in an elliptical path and at a different speed. Although it is possible to calculate the mean distance from the sun to each planet, because of their different orbital speeds and paths it is very difficult to determine the distances between planets at one specific time. The mean distance is the average of all the distances from the maximum to the minimum.

At this particular period of astronomical time, however, a very peculiar event has happened. All the outer planets are virtually lined up. Because of this unusual phenomenon, it was possible for Voyager II to pass near Jupiter, Saturn, and Uranus on one trip. Voyager II began its trip in 1978 and the plan is for it to pass Pluto in 1990. Although Voyager will not pass as close to Pluto as it did to Jupiter, Saturn and Uranus, it will still gather excellent new data on Pluto.

THE EVOLUTION OF THE UNIVERSE

The Universe is the true home of humankind. Our Sun is only one star in the billions that comprise the Milky Way Galaxy, which in turn is only one of the billions of galaxies astronomers have already identified. Our beautiful planet is one of nine in our Solar System. Understanding our Universe is not just an intellectual and philosophical quest, but a requirement for continuing to live in, and care for, our tiny part of it, as our species expands outward into the Solar System.

Beginnings: The Big Bang, the Universe, and Galaxies

In the 1920s scientists concluded that the Universe is expanding from its origin in an enormous explosion—the "Big Bang"—10 to 20 billion years ago. In the future, it could either expand forever or slow down and then collapse under its own weight. Recent studies in particle physics suggest that the Universe will expand forever, but at an ever decreasing rate. For this to be true, there must be about ten times more matter in the Universe than has ever been observed; this "hidden matter" may be in the form of invisible particles that are predicted to exist by modern theory. Thus, in addition to normal galaxies there may be invisible "shadow galaxies" scattered throughout space.

The Universe contains 100 billion or more galaxies, each containing billions of stars. Our Galaxy, the Milky Way, is the home of a trillion stars, many of which resemble our Sun. Each of these stars, when it is formed from an interstellar cloud, is endowed with hydrogen and helium—simple chemical elements that formed in the Big Bang, as well as with heavier elements that formed in previous stellar furnaces. Hydrogen is consumed by a thermonuclear fire in the star's core, producing heavier chemical elements that accumulate there before becoming fuel for new, higher temperature burning. In massive stars, the process continues until the element iron dominates the core. No further energy-producing nuclear reactions are then possible, so the core collapses suddenly under its own weight, producing vast amounts of energy in a stellar explosion known as a supernova. The temperature in a supernova is so high that virtually all of the chemical elements produced are flung into space, where they are available to become incorporated in later generations of stars. About once per century a supernova explosion occurs in each galaxy, leaving behind a compact object that may be a neutron star—as dense as an atomic nucleus and only a few miles in diameter—or a stellar black hole, in which space-time is so curved by gravity that no light can escape. . .

A Grand Synthesis

The Universe has evolved from the Big Bang to the point we see it today, with hundreds of billions of galaxies and perhaps countless planets. There is no evidence that the processes which govern the evolution from elementary particles to galaxies to stars to heavy elements to planets to life to intelligence differ significantly elsewhere in the Universe. By integrating the insights obtained from virtually every branch of science, from particle physics to anthropology, humanity may hope one day to approach a comprehensive understanding of our position in the cosmos.

From: Pioneering the Space Frontier The Report of The National Commision on Space, Bantam Books, 1986.

LIFE: EARTH AND THE UNIVERSE

The Evolution of Earth and Its Life Forms

Earth is the only one of our Solar System's nine planets that we know harbors life. Why is Earth different from the other planets? Life as we know it requires tepid liquid water, and Earth alone among the bodies of the Solar System has had that throughout most of its history.

Biologists have long pursued the hypothesis that living species emerge very gradually, as subtle changes in the environment give decisive advantages to organisms undergoing genetic mutations. The recent discovery that the extinction of the dinosaurs (and many other species as well) some 65 million years ago appears to have coincided with the collision of Earth with a large object from outer space—such as a comet or asteroid—has led to new interest in "punctuated equilibrium." According to this concept, a drastic change in environment, in this case the pall cast upon Earth by the giant cloud of dust that resulted from the collision, can destroy some branches of the tree of life in a short span of time, and thereby open up new opportunities for organisms that were only marginally competitive before. The story of the evolution of life on Earth—once the sole province of biology—thus depends in part upon astronomical studies of comets and asteroids which may collide with our planet, the physics of high-velocity impact, and the complex processes that govern the movement of dust in Earth's atmosphere.

Atmospheric scientists are finding that within such short times as decades or centuries the character of life on Earth may depend upon materials originating in the interior of the planet (including dust and gases from volcanoes), chemical changes in the oceans and the atmosphere (including the increase in carbon dioxide due to agricultural and industrial activity), and specific radiations reaching us from the Sun (such as the ultraviolet rays which affect the chemical composition of Earth's atmosphere). Through mechanisms still not understood, changes in Earth's climate may in turn depend upon the evolution of life. It has become apparent that life on Earth exists in a complex and delicate balance not only with its own diverse elements, but with Earth itself, the Sun, and probably even comets and asteroids. Interactions among climatology, geophysics, geochemistry, ecology, astronomy, and solar physics are all important as we contemplate the future of our species; space techniques are playing an increasing role in these sciences.

Space techniques are also valuable for studying Earth's geology. The concept of continental drift, according to which the continents change their relative positions as the dense rocks on which they rest slowly creep, is proving to be a key theory in unraveling the history of Earth as recorded in the layers of sediments laid down over millions of years.

From: Pioneering the Space Frontier The Report of The National Commision on Space, Bantam Books, 1986.

The Possibility of Other Life in the Universe

Are we alone in the Universe? Virtually all stars are composed of the same chemical elements, and our current understanding of the process by which the Solar System formed suggests that all Sun-like stars are likely locales for planets. The search for life begins in our own Solar System, but based on the information we have gleaned from robotic excursions to Mercury, Venus, the Moon, Mars, Jupiter, Saturn, and Uranus, it now appears that Mars, and perhaps Titan, a moon of Saturn, are the most likely candidates for the existence of rudimentary life forms now or in the past.

The existence of water on Mars in small quantities of surface ice and in atmospheric water vapor, and perhaps in larger quantities frozen beneath the surface, leaves open the possibility that conditions on Mars may once have been favorable enough to support life in some areas. Samples returned from regions where floods have occurred may provide new clues to the question of life on Mars.

Titan has a thick atmosphere of nitrogen, along with methane and traces of hydrogen cyanide—one of the building blocks of biological molecules. Unfortunately, the oxygen atoms needed for other biological molecules are missing, apparently locked forever in the ice on Titan's surface.

How do we search for planets beyond our Solar System? The 1983 Infrared Astronomy Satellite discovered that dozens of stars have clouds of particles surrounding them emitting infrared radiation; astrophysicists believe that such clouds represent an early stage in the formation of planets. Another technique is to track the position of a star over a number of years. Although planets are much less massive than stars, they nevertheless exert a significant gravitational force upon them, causing them to wobble slightly. Through a principle called interferometry, which combines the outputs of two telescopes at some distance apart to yield very sharp images, it should be possible to detect planets—if they exist—by the perturbations they cause as they orbit nearby stars similar to our Sun. With sufficiently large arrays of telescopes in space we might obtain images of planets beyond the Solar System. By searching for evidence of water and atmospheric gases we might even detect the existence of life on those planets.

If life originated by the evolution of large molecules in the oceans of newly-formed planets, then other planets scattered throughout our Galaxy could be inhabited by living species, some of which may possess intelligence.

If intelligent life does exist beyond our Solar System, we might detect its messages. The Search for Extraterrestrial Intelligence, or SETI, is a rapidly advancing field. For several decades it has been technically possible to detect radio signals (if any) directed at Earth by alien civilizations on planets orbiting nearby stars. It is now possible to detect such signals from anywhere in our Galaxy, opening up the study of over 100 billion candidate stars. Such a detection, if it ever occurs, would have profound implications not only for physical and biological sciences, but also for anthropology, political science, philosophy, and religion. Are we alone? We still do not know.

From: Pioneering the Space Frontier The Report of The National Commision on Space, Bantam Books, 1986.

EXPLORATION OF THE OUTER PLANETS

Beyond the asteroid belt lie four giant ringed planets (Jupiter, Saturn, Uranus, and Neptune), the curiously small world Pluto, more than 40 moons (two of which—Titan and Ganymede—are larger than the planet Mercury), and two planetary magnetospheres larger than the Sun itself. The center of gravity of our planetary system is here, since these worlds (chiefly Jupiter and Saturn) account for more than 99 percent of the mass in the Solar System outside of the Sun itself. The outer planets, especially Jupiter, can provide unique insights into the formation of the Solar System and the Universe. Because of their large masses, powerful gravitational fields, and low temperatures, these giant planets have retained the hydrogen and helium they collected from the primordial solar nebula.

The giant worlds of the outer Solar System differ greatly from the smaller terrestrial planets, so it is not surprising that different strategies have been developed to study them. The long-term exploration goal for terrestrial planets and small bodies is the return of samples to laboratories on Earth, but the basic technique for studying the giant planets is the direct analysis of their atmospheres and oceans by means of probes.

Atmospheric measurements, which will be undertaken for the first time by Galileo at Jupiter, provide the only compositional information that can be obtained from a body whose solid surface (if any) lies inaccessible under tens of thousands of miles of dense atmosphere. Atmospheric probe measurements, like measurements on returned samples, will provide critical information about cosmology and planetary evolution, and will permit fundamental distinctions to be made among the outer planets themselves.

The outer Solar System provides us with a special challenge, one that can be described as an embarrassment of scientific riches. It presents an overwhelming number of potential targets beyond the planets: The larger moons (Titan and Triton), the smaller moons (including the diverse Galilean satellites), the rings, and the magnetospheres.

Exciting possible missions include: (1) Deep atmospheric probes (to 500 bars) to reach the lower levels of the atmospheres of Jupiter and Saturn and measure the composition of these planets; (2) hard and soft landers for various moons, which could emplace a variety of seismic, heat-flow, and other instruments; (3) close-up equipment in low orbits; (4) detailed studies of Titan, carried out by balloons or surface landers; (5) on-site, long-term observations of Saturn's rings by a so-called "ring rover" spacecraft able to move within the ring system; and (6) a high-pressure oceanographic probe to image and study the newly-discovered Uranian Ocean.

From: Pioneering the Space Frontier The Report of The National Commision on Space, Bantam Books, 1986.

The Possibility of Life in the Universe
A Fictional Excerpt

"On the third day a pair of Drake's students from Cornell explained to laymen in the group the frightening equation for the probability of life in some other planet in the Galaxy:

$$N = N \times f_1 \times f_2 \times f_3 \times f_4 \times f_5 \times f_6$$

When it was placed on the blackboard the non-scientific members groaned, but the speaker quickly explained...

All it means is that the first N represents the number of civilizations in our Galaxy capable of communicating with us right now. That's the figure we must have to make our discussion reasonable. The second N is a figure we seek to make our discussion practical. N is a very large number representing all the known stars in the galaxy. Some experts say one hundred billion, some say four. In our example, I'll take four. The next six letters with their subscripts represent fractions, with each subscript standing for a crucial word or concept. When you multiply the very large number by the six fractions, you get a constantly diminishing number of possible civilizations.

First fraction:	The portion of stars which have planetary systems... this fraction must be considerably smaller than one-half, more likely one quarter.
Second fraction:	The portion of planets with an ecology to support life; perhaps one half.
Third fraction:	The portion of the eligible planets on which life actually does develop; the biologists believe it must almost be nine tenths.
Fourth fraction:	What portion of those with life develop intelligent forms? Given enough time we think it could be one tenth.
Fifth fraction:	The portion of civilizations with intelligent life which learn to communicate outwardly; perhaps one third.
Sixth fraction:	What is the longevity of technical civilization? The only hard evidence we have is our own experience on earth. Four and a half billion years old. Technically competent to communicate forty-five years....

$$\frac{45}{4{,}500{,}000{,}000} \quad \text{or} \quad \frac{1}{100{,}000{,}000}$$

Multiplying the fractions:

This means there are at least 15 galaxies with whom we might communicate."*

*Editor's Note:

$$N = N \times f_1 \times f_2 \times f_3 \times f_4 \times f_5 \times f_6$$

$$N = 4 \times 10^{11} \times \frac{1}{4} \times \frac{1}{2} \times \frac{9}{10} \times \frac{1}{10} \times \frac{1}{3} \times \frac{45}{4{,}500{,}000{,}000}$$

$$N = 4 \times 10^{11} \times \frac{1}{4} \times \frac{1}{2} \times \frac{9}{10} \times \frac{1}{10} \times \frac{1}{3} \times \frac{1}{10^8}$$

$$N = \frac{4}{4} \times \frac{1}{2} \times \frac{1}{3} \times \frac{9}{10^2} \times 10^{11} \times \frac{1}{10^8}$$

$$N = \frac{3}{2} \times 10^1 = 15$$

From: Space by James Mitchener.

Typical Student Questions
and
Discussion

THE SOLAR SYSTEM

Is there any air in space ?

No. There is no atmosphere as we know it. There do exist gases (hydrogen, helium, etc.) and radiation, but there is literally nothing in space. It is a void, a near perfect vacuum.

Is it hot in space ? Is it cold ?

It depends where you are. If you are in the sunlight, with direct exposure to the sun (i.e., with no space suit), then your skin would reach over 200 degrees F on the surface. If you were in the shade (i.e. behind a planet) , your skin would experience -200 degrees F. So it is both hot and cold in space.

Is there any sound in space ?

No. Since there is no atmosphere for the sound waves to travel through, there is no sound in space.

What would happen if you opened a can of COKE in space ?

If the COKE was shaken up, it would still spray when it was opened. However the spray would not fall to the ground as it does here on Earth; it would continue floating away from the can. Any particle given a motion will continue in motion until it is acted upon by another force. In space there is no friction to act upon the spray.

If you were floating in space, could you lift a very heavy object like an elephant?

Yes. A "weightless" environment means that objects have no weight. Therefore you could pick up any object. However an object's mass is still important. Because the elephant is more massive than you are, it would be difficult to control the elephant as you lifted it, but you would still be able to it (in fact, you could lift it on your finger tip).

What would happen if you threw the elephant to somebody ?

The elephant will continue in motion until it is acted upon by some force. If you attempted to catch the elephant, the inertia of the elephant's motion would carry you right along with it. You would not be able to stop it because the elephant is more massive than you are.

If you threw a ball in space, what would happen to it ?
What would happen to you ?

Again, the ball would continue in motion indefinitely until it hit something. The act of throwing the ball would cause you to move in the opposite direction and you would continue in motion until you hit something.

Do they have radio stations in space ?

Yes. Radio waves do not need a medium like air to travel through. In fact, scientists are using radio waves to investigate the possibility of life elsewhere in the universe.

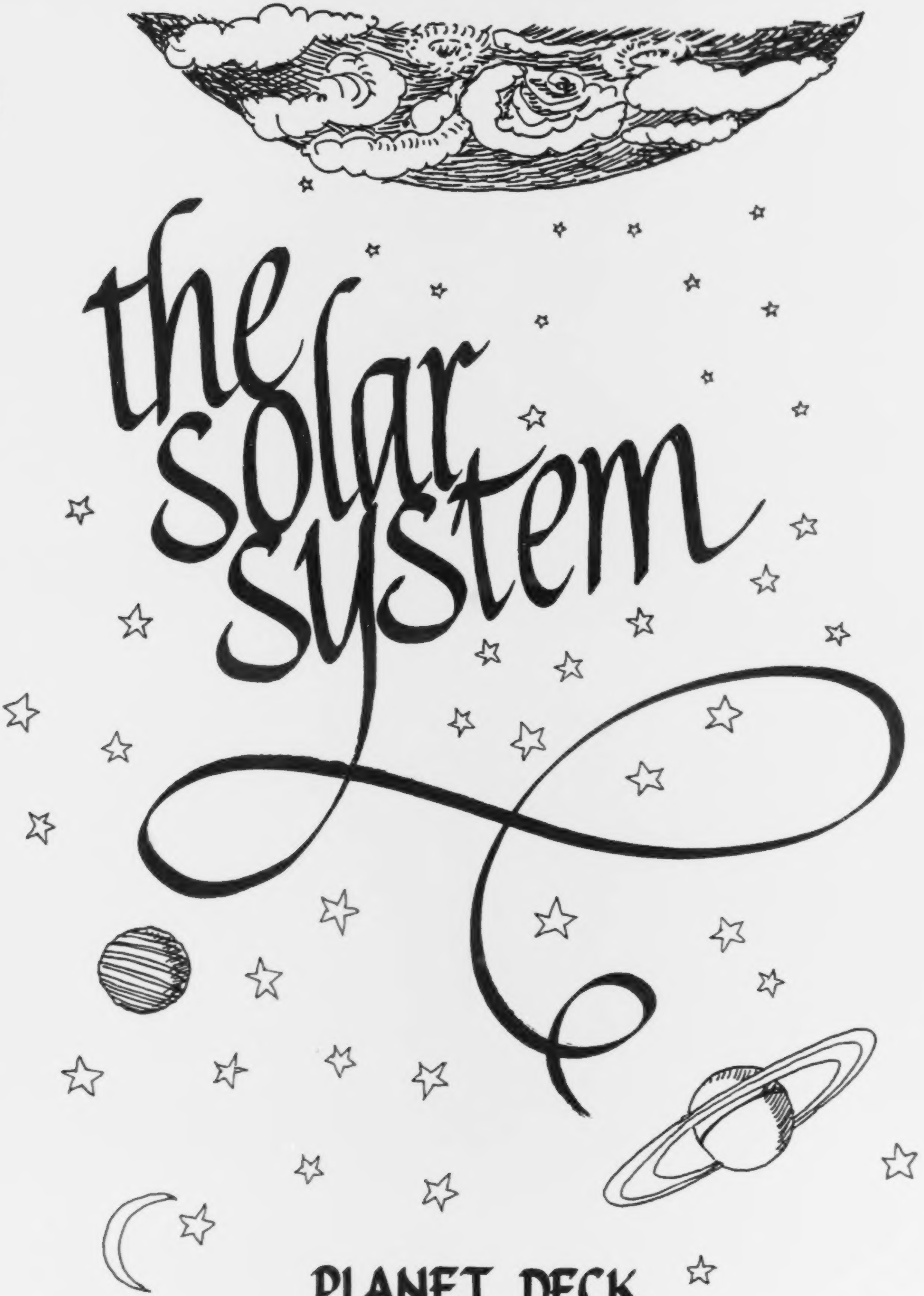
Could you live on the moon ?

Yes. However, the moon has no atmosphere so you would always need to wear a space suit or be in an enclosed building like a moon base.

Do you think there is life beyond our planet ?

Just remember that our solar system is only one of millions in the Milky Way Galaxy and there are 10 billion Galaxies in the Universe.

the solar system



PLANET DECK

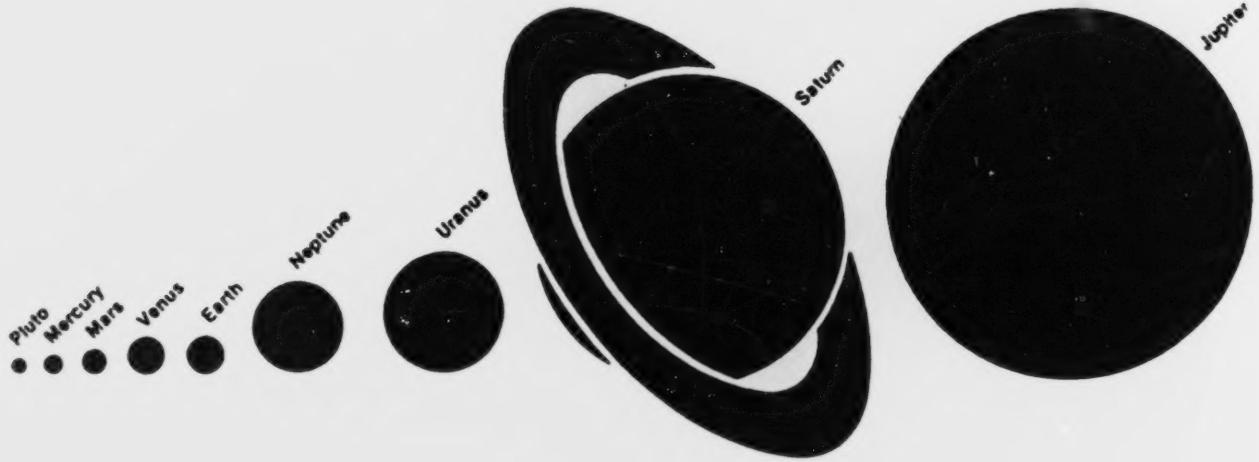
Summary of Facts for Planets, Moon & Sun

	MERC.	VENUS	EARTH	MOON	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO	SUN
Average Distance from Sun (Miles)	36,000,000	67,200,000	92,900,000	238,900 from earth	141,515,000	483,500,000	886,000,000	1,782,000,000	2,794,000,000	3,674,000,000	25 million to nearest star
Length of Year (Period of Orbit)	88.0 days	224.7 days	365.26 days	27.32 days	1.88 Years	11.86 Years	29.46 Years	84.01 Years	164.8 Years	247.7 Years	246 million to next galaxy
Length of Day (Period of Rotation)	58 days	243 days	24 hours	27 days	24 hours	9 hours	10 hours	15 hours	18 hours	6 days	25 days
Average Orbital Speed (MPH)	107,300	78,500	66,500	2,300	54,100	29,300	21,600	15,300	12,200	10,600	560,000 around galactic center
Equatorial Diameter (Miles)	3031	7521	7927	2160	4197	88,733	74,600	31,600	30,200	2,113	865,000
Mass (Tons)	3.53×10^{20}	5.34×10^{21}	6.59×10^{21}	8.24×10^{19}	7.08×10^{20}	2.09×10^{24}	6.26×10^{23}	9.55×10^{22}	1.15×10^{23}	1.12×10^{19}	2.19×10^{27}
Escape Velocity (MPH)	9,619	23,042	25,055	5,324	11,185	141,828	88,139	48,096	54,136	751	1,378,000
Temperature Max °F	660	896	136.4	225	80	53,500	*	*	*	-382	27,000,000
Temperature Min °F	-270	-27	-126.9	-243	-190	-140	-292	-346	-364	-390	10,800
# Moons	0	0	1	-	2	16+rings	23?+rings	5+rings	2	1	9 planets
Eccentricity of Orbit	0.206	0.007	0.017	0.055	0.093	0.048	0.056	0.047	0.009	0.250	—

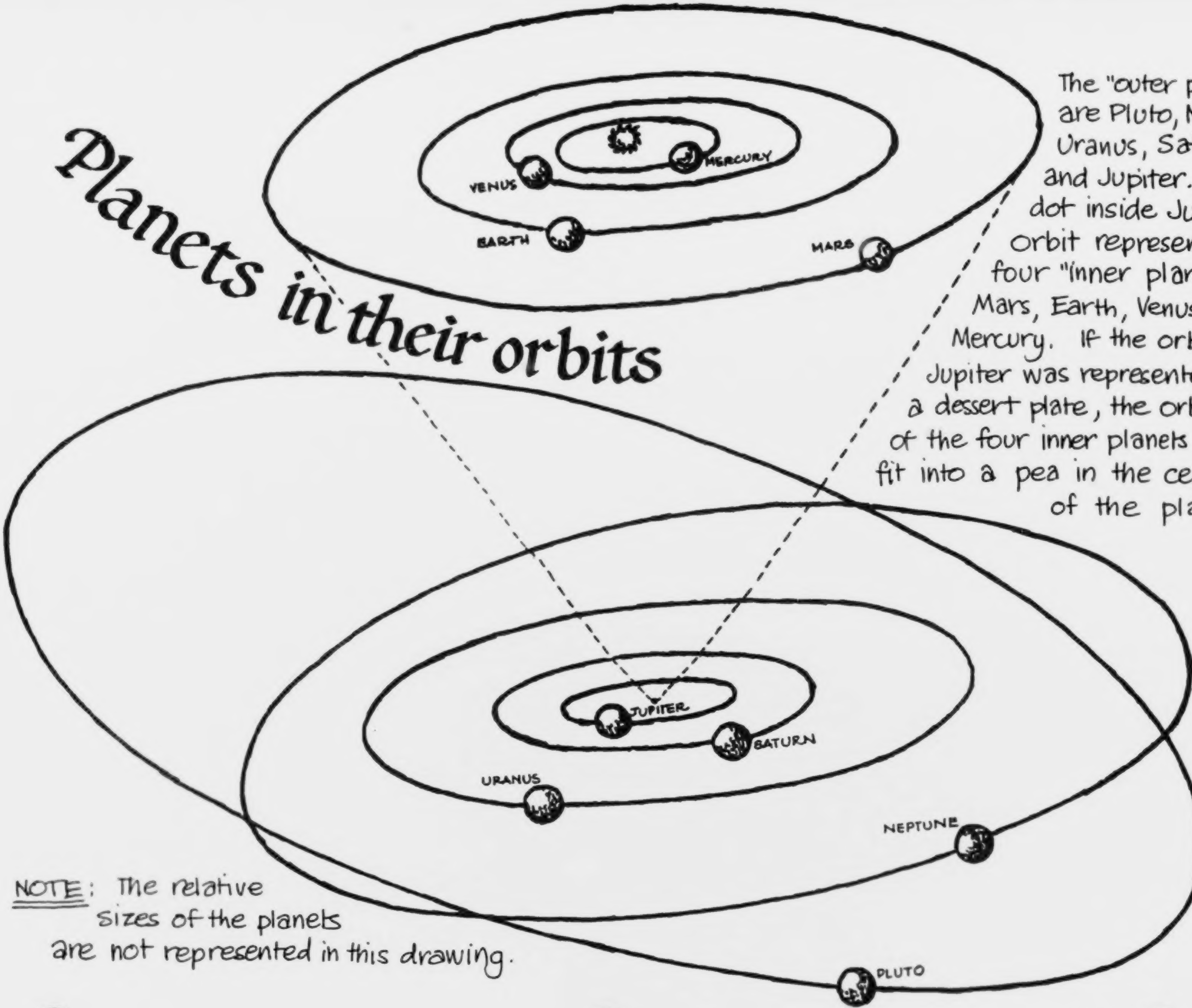
* Scientists do not yet know.

Summary of Facts for Planets, Moon & Sun

Scaled Dimension	MERC.	VENUS	EARTH	MOON	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO	SUN
Equatorial Diameter	.382	.949	1	.2725	.5326	11.19	9.41	3.98	3.81	0.24?	109
Mass	.055	.815	1	.012	.107	317.9	95.17	14.56	17.24	.002?	332,946
Volume	.056	.855	1	.020	.151	1,403	833	63.0	55.3	.013?	1,300,000
Surface Gravity	.38	.90	1	.16	.38	2.6	1.2	.93	1.4	0.03?	27.8



Planets in their orbits



The "outer planets" are Pluto, Neptune, Uranus, Saturn and Jupiter. The dot inside Jupiter's orbit represents the four "inner planets:" Mars, Earth, Venus and Mercury. If the orbit of Jupiter was represented by a dessert plate, the orbits of the four inner planets would fit into a pea in the center of the plate!

NOTE: The relative sizes of the planets are not represented in this drawing.

APPROXIMATE DISTANCES BETWEEN PLANETS

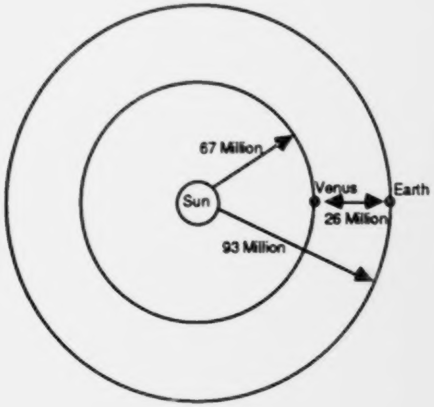
Planets travel in their orbits at different speeds. Thus, the distance between them is constantly changing.

A synodic period is that time when the planets are "lined up" coming straight out from the sun. It is during these synodic periods that the planets are closest together.

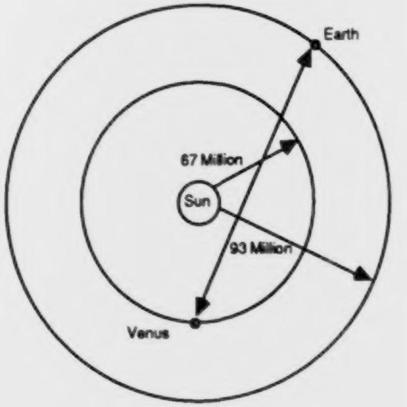
Distances

	Dist. to Sun	Dist. to Mercury	Dist. to Venus	Dist. to Earth	Dist. to Mars	Dist. to Jupiter	Dist. to Saturn	Dist. to Uranus	Dist. to Neptune	Dist. to Pluto
Mercury	35,980,103	0	31,260,012	56,983,012	105,662,248	447,645,000	854,632,901	1,746,039,900	2,758,463,907	3,618,429,988
Venus	67,240,115	31,260,012	0	25,723,000	74,402,236	416,384,988	823,372,889	1,714,779,888	2,727,203,895	3,587,169,976
Earth	92,963,115	56,983,012	25,723,000	0	48,679,236	390,661,988	797,649,889	1,689,056,888	2,701,480,895	3,561,446,976
Mars	141,642,351	105,662,248	74,402,236	48,679,236	0	341,982,752	748,970,653	1,640,377,652	2,652,801,659	3,512,767,740
Jupiter	483,625,103	447,645,000	416,384,988	390,661,988	341,982,752	0	406,987,901	1,298,394,900	2,310,818,907	3,170,784,988
Saturn	890,613,004	854,632,901	823,372,889	797,649,889	748,970,653	406,987,901	0	891,406,999	1,903,831,006	2,763,797,087
Uranus	1,782,020,003	1,746,039,900	1,714,779,888	1,689,056,888	1,640,377,652	1,298,394,900	891,406,999	0	1,012,424,007	1,872,390,088
Neptune	2,794,444,010	2,758,463,907	2,727,203,895	2,701,480,895	2,652,801,659	2,301,818,907	1,903,831,006	1,012,424,007	0	859,966,081
Pluto	3,654,410,091	3,618,429,988	3,587,169,976	3,561,446,976	3,512,767,740	3,170,784,988	2,763,797,087	1,872,390,088	859,966,081	0

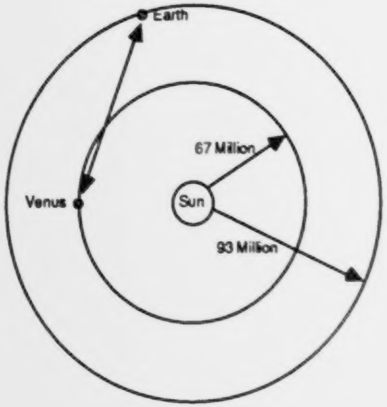
Synodic Period



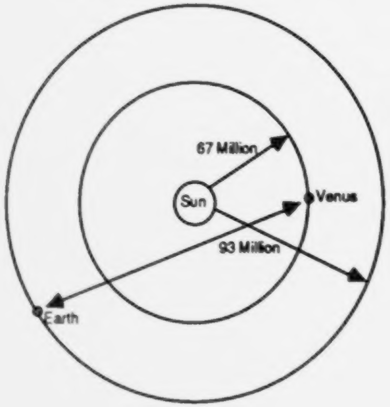
1/6 of a Year Later

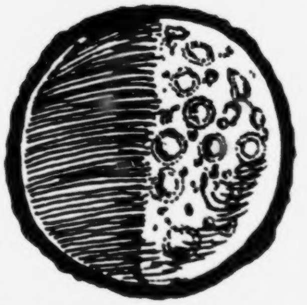


1/3 of a Year Later



2/3 of a Year Later





PLUTO

"The Oddity of the Solar System"

Pluto is the oddity of the solar system, because it has little in common with the other gas giants. Pluto travels in an oval shaped orbit that is tilted from the plane of the other planets' orbits.

Pluto may not always have been a planet. It previously may have been a moon of Neptune.

Distance from the sun:	3,674,000,000 miles
Average Diameter:	2,113 miles

Named after a Greek god
who ruled the land of the dead.

MAJOR FEATURES OF PLUTO:

- Length of "day": 6 Earth Days
  (Time to make complete rotation around its axis)
- Length of "year": 247.7 Earth Years
  (Time to make one orbit around sun)
- Mass: 1.12×10^{19} Tons
- Average Orbital Speed: 10,600 MPH
- Surface Gravity: 0.03 x Earth's Gravity
- Escape Velocity: 751 MPH
- Number of Moons: 1
- Number of Rings: 0
- Exploration History: None to date.

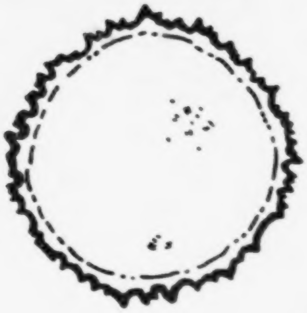
SUN

"The Kingpin of Our Solar System"

The sun is the star that is the closest to earth. It is a huge ball of gas and is the source of our heat, light, wind, and rain.

Explosions are happening on the sun all the time, giving off a tremendous amount of heat and light. The sun spins on its own axis. It also travels around the center of its family of stars, the Milky Way Galaxy. Scientists estimate it will take 246 million "Earth" years to complete this trip.

Distance to the Next Galaxy: 246,000,000 miles
Average Diameter: 865,000 miles



MAJOR FEATURES OF THE SUN:

- Length of "day": 25 Earth Days
  (Time to make complete rotation around its axis)
- Length of "year": 246 Million Earth Years
  (Time to make one orbit around its family of stars)
- Mass: 2.19×10^{27} Tons
- Average Orbital Speed: 560,000 MPH around gallactic center
- Escape Velocity: 1,378,000 MPH
- Number of Planets: 9

MOON

"Our Closest Neighbor"

The moon is a big rock that is a satellite of earth. A satellite travels around an object in an orbit or path.

The moon has extremes of temperature ranging from -243° F to 225° F. The Moon has no air or water and therefore has no wind or sound or rain.

Only 59% of the moon is visible from the earth.

Distance from the earth: 238,900 miles
Average Diameter: 2,160 miles

MAJOR FEATURES OF THE MOON:

- Length of "day": 27 Earth Days
  (Time to make complete rotation around its axis)
- Length of "year": 27.32 Earth Days
  (Time to make one orbit around the earth)
- Mass: 8.24×10^{19} Tons
- Average Orbital Speed: 2300 MPH
- Surface gravity: 0.16 x Earth
- Escape Velocity: 5,324 MPH

- Exploration History: Apollo Program 1969-1972
  Moon Exploration and Landing.
  Moon studied by Ranger, Surveyor and Lunar Orbiter.

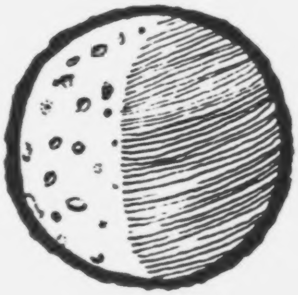
MERCURY

"The Hidden Planet"

Mercury is a small, fast moving planet. It is so close to the sun that it is usually lost in the sun's glare. It is visible to earth just after sunset or just before dawn. Even then it is obscured by haze and dust in the earth's atmosphere.

Since Mercury is small, its gravitational pull is not very strong. It is not even strong enough to hold the planet's atmosphere. Without an atmosphere, there is nothing above the surface of Mercury to reflect its own light. That's why Mercury is so dark.

Distance from the sun:	36,000,000 miles
Average Diameter:	3,031 miles



Named for the speedy messenger
of the Roman gods.

MAJOR FEATURES OF MERCURY:

- Length of "day": 58 Earth Days
  (Time to make complete rotation around its axis)
- Length of "year": 88 Earth Days
  (Time to make one orbit around sun):
- Mass: 3.53×10^{20} Tons
- Orbital Speed: 107,300 MPH
- Surface Gravity: 0.38 x Earth's Gravity
- Escape Velocity: 9,619 MPH
- Number of Moons: 0
- Number of Rings: 0
- Exploration History: Mariner 10 Fly-by
  March 1974
  September 1974

EARTH

"Our Home Base"

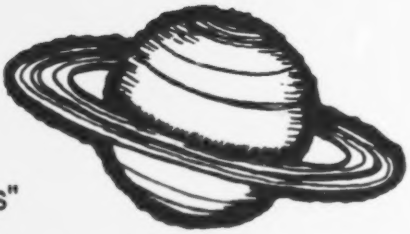
Earth is a big, nearly round ball of stone and metal, covered with water, rocks and dirt. Day and night are caused by the spinning of the earth on its axis, exposing different regions to rays of the sun.

Earth's atmosphere, made up of nitrogen (78%), oxygen (21%) as well as helium, carbon dioxide, and argon, does not go on forever. It becomes thinner and thinner as you travel away from earth, until at a point about two hundred miles up, where the atmosphere fades and outer space begins.

Distance from the sun:	92,900,000 miles
Average Diameter:	7,927 miles

MAJOR FEATURES OF EARTH:

- Length of "day": 24 Earth Hours
  (Time to make complete rotation around its axis)
- Length of "year": 365.26 Earth Days
  (Time to make one orbit around sun)
- Mass: 6.59×10^{21} Tons
- Average Orbital Speed: 66,500 MPH
- Surface Gravity: 32 feet/sec/sec
- Average Escape Velocity: 25,055 MPH
- Number of Moons: 1
- Number of Rings: 0
- Exploration History:
  Explorer 1 discovered intense radiation zone, called Van Allen Radiation Region.
  Various satellites have helped understand features of earth, its weather patterns and its resources.



SATURN

"The Planet of Exquisite Rings"

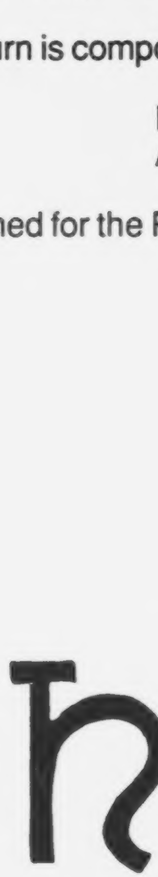
No planet in the solar system is adorned with rings as brilliant as Saturn's. Each of Saturn's rings is made of tiny particles of orbiting ice and rock. Scientists believe the rings were formed either from a moon or passing body which ventured too close and was torn apart.

Saturn is composed mostly of hydrogen, and has a subtle butterscotch color.

Distance from the sun:	886,000,000 miles
Average Diameter:	74,600 miles

Named for the Roman god of Agriculture.

MAJOR FEATURES OF SATURN:



- Length of "day": 10 Earth Hours
  (Time to make complete rotation around its axis)
- Length of "year": 29.46 Earth Years
  (Time to make one orbit around sun)
- Mass: 6.26×10^{23} Tons
- Average Orbital Speed: 21,600 MPH
- Surface Gravity: 1.2 x Earth's Gravity
- Escape Velocity: 88,139 MPH
- Number of Moons: 23
- Number of Rings: 1000+
- Exploration History:

Pioneer 11	1979	Saturn Fly-by
Voyager 1	1980	Saturn & Jupiter Fly-by
Voyager 2	1981	Tour of Planets

JUPITER

"The Giant of the Solar System"

Jupiter is the largest of the solar system's planets. It is something of a mini-solar system, with 16 known moons above its clouds.

Jupiter is filled with poisonous gas and has no solid surface. Only towards its center does the gas become liquid and then solid.

Jupiter is known for its "Giant Red Spot" that covers an area more than three times the size of earth. The red spot is a storm that has been raging for years.

Distance from the sun:	483,500,000 miles
Average Diameter:	88,733 miles

Named for the king of Roman gods,
because it is the largest planet.

MAJOR FEATURES OF JUPITER:

- Length of "day": 9 Earth Hours
  (Time to make complete rotation around its axis)
- Length of "year": 11.86 Earth Years
  (Time to make one orbit around sun)
- Mass: 2.09 x 10^{24} Tons
- Average Orbital Speed: 29,300 MPH
- Surface gravity: 2.6 x Earth's Gravity
- Escape Velocity: 141,828 MPH
- Number of Moons: 16
- Number of Rings: 1
- Exploration History:

Pioneer 10	1973	Fly-by
Pioneer 11	1974	Fly-by
Voyager 1	1979	Tour of Jupiter
Voyager 2	1979	Survey of Jupiter

Galileo Project being readied for 1980's

MARS

"The Red Planet"

Mars is covered with dust and rocks containing a reddish mineral. That's why Mars looks red and is often called the Red Planet. Mars has long been considered the solar system's prime candidate for harboring extraterrestrial life. Mars turns on its axis,which results in different seasons. Seasons would be conducive to supporting the growth of vegetation.

Astronomers, looking at Mars, saw what appeared to be straight lines crisscrossing the surface, leading to the notion that intelligent beings built canals on the planet. The lines turned out to be an illusion.

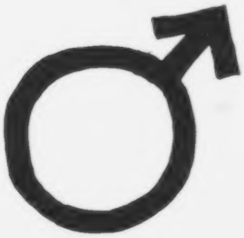
Distance from the sun:	141,515,000 miles
Average Diameter:	4,197 miles

Named for the god of war,
a warrior covered with blood.

MAJOR FEATURES OF MARS:

- Length of "day": 24 Earth Hours
  (Time to make complete rotation around its axis)
- Length of "year": 1.88 Earth Years
  (Time to make one orbit around sun)
- Mass: 7.08 x 10^{20} Tons
- Average Orbital Speed: 54,100 MPH
- Surface Gravity: 0.38 x Earth's Gravity
- Escape Velocity: 11,185 MPH
- Number of Moons: 2
- Number of Rings: 0
- Exploration History:

Mariner 4	1965	Fly-by
Mariner 6	1969	Fly-by
Mariner 7	1969	Fly-by
Mariner 9	1971	Orbit of Mars
Viking 1	1976	Orbit of Mars
Viking 2	1979	Unmanned landing



VENUS

"The Brightest Planet"

Venus is sometimes called earth's sister planet. Venus is the closest to the earth and of a similar size. In their orbits, Earth and Venus get as close as 25 million miles and as far apart as 160 million miles. Venus has been called both the morning and evening star, because it can be seen just before morning when it is travelling away from earth and just before evening when it is coming toward earth.

Venus is surrounded by thick clouds filled with drops of acid. The clouds hold in the heat and make Venus very hot.

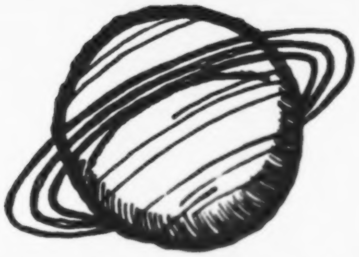
Distance from the sun:	67,200,000 miles
Average Diameter:	7,521 miles

Named for the Roman god
of Springtime and Flowers.

♀

MAJOR FEATURES OF VENUS:

- Length of "day": 243 Earth Days
  (Time to make complete rotation around its axis)
- Length of "year": 224.7 Earth Days
  (Time to make one orbit around sun)
- Mass: 5.34×10^{21} Tons
- Average Orbital Speed: 78,500 MPH
- Surface gravity: 0.90 x Earth's Gravity
- Escape Velocity: 23,042 MPH
- Exploration History:
  - 1962 Mariner 2 Fly-by
  - 1967 Mariner 5 Fly-by
  - 1974 Mariner 10 Fly-by
  - 1978 Pioneer Venus 1
    First spacecraft to orbit Venus
  - 1978 Pioneer Venus 2
    Probes placed on Venus
- Interesting Notes:
  - Evidence of Volcanic Activity
  - About 97% of atmosphere is carbon dioxide
  - Appears to have two continent-like areas, one the size of Africa, the other half the size of Australia.



URANUS

"The Goal of Voyager"

Uranus is much bigger than earth, but it is so far away that it is at the limit of naked eye vision. Its atmosphere contains methane which gives the planet its greenish color.

Clouds sweep across the face of the planet at a faster rate than on earth. They have been clocked to be traveling more than 220 mph.

Distance from the sun:	1,782,000,000 miles
Average Diameter:	31,600 miles

Named for the Greek god of the sky.

MAJOR FEATURES OF URANUS:

- Length of "day": 15 Earth Hours
  (Time to make complete rotation around its axis)
- Length of "year": 84.01 Earth Years
  (Time to make one orbit around sun)
- Mass: 9.55×10^{22} Tons
- Average Orbital Speed: 15,300 MPH
- Surface Gravity: 0.93 x Earth's Gravity
- Escape Velocity: 48,096 MPH
- Number of Moons: 5
- Number of Rings: 5
- Exploration History: 1986 Voyager 2 Fly-by

NEPTUNE

"The Logically Discovered Planet"

Scientists knew there was a Neptune even before they saw it. As they watched Uranus, they noticed something was affecting its orbit. They believed there was another planet beyond Uranus. They finally found it in 1846.

Neptune's atmosphere is like that of Uranus, containing methane, along with hydrogen and helium. It, too, looks blue-ish green.

Distance from the sun:	2,794,000,000 miles
Average Diameter:	30,200 miles

Named for the Roman god of the Sea.

MAJOR FEATURES OF NEPTUNE:

- Length of "day": 18 Earth Hours
  (Time to make complete rotation around its axis)
- Length of "year": 164.8 Earth Years
  (Time to make one orbit around sun)
- Mass: 1.15×10^{23} Tons
- Average Orbital Speed: 12,220 MPH
- Surface Gravity: 1.4 x Earth's Gravity
- Escape Velocity: 54,136 MPH
- Number of Moons: 2
- Number of Rings: 0
- Exploration History:
  Scheduled to be visited by Voyager 2 in 1989

the Shuttle System

data

SHUTTLE BACKGROUND INFORMATION

(ALL YOU NEED TO KNOW FOR THIS MODULE)

From the beginning of time, man has longed to know more about space. The ancient Chinese first developed rocketry. Using the principle of Newton's Third Law (for every action there is an equal and opposite reaction), the Chinese invented a gunpowder rocket. Much like releasing an inflated balloon, gas from a controlled explosion bursts out of the tail toward the ground, propelling the rocket in the opposite direction into the air. It became clear to early space scientists that by aiming a large enough rocket skyward, and propelling it with enough force, one would be able to send a spacecraft into space.

How large an explosion is necessary to lift a rocket? The space craft must travel fast enough to escape from the earth's powerful gravitational pull. Through mathematical calculations, it was determined that an object travelling at 22,055 miles/hour will escape the earth's gravity.

The United States has developed spacecraft and planned missions to continue this quest to fly in space. Our space program has included the Mercury Program (the earliest flights), the Gemini program (long flights around the earth), and the Apollo Program (flights to the moon). Early space exploration consisted of sending small payloads into space so that the rockets and fuels were relatively simple to develop. The Atlas rocket was the first rocket used. As the sizes of the payloads and the distances people hoped to travel increased, the sizes and the costs of rockets also escalated. By the time we were sending three astronauts 238,900 miles to the moon in a Saturn rocket, costs had increased to 2 billion dollars for each trip.

A major problem of the Apollo missions was that the expensive Saturn rockets used for each launch were totally destroyed during the mission. It was decided that a partially reusable spaceship was needed to reduce some of the costs. In addition, NASA started into the commercial business of delivering, repairing, and retrieving satellites and running experiments for contractors in the weightlessness of space (For further information, see the Fact Book, types of missions.)

The spaceship designed for the purposes of reducing and controlling costs was the space shuttle, with its re-usable features. The Shuttle System consists of the shuttle itself, two solid rocket boosters and an external tank that carries fuel for the rocket engines. The basic components of the shuttle are the Orbiter, which includes the flight deck, the mid-deck and crew quarters and the payload bay, which is like the trunk of a car. The payload bay is where satellites, the robot arm, and sometimes the European Space Agency (ESA) lab (extra space for carrying out experiments) are carried into orbit.

The shuttle takes off into space as a regular rocket would, with a huge thrust given by the two large solid rocket boosters on each side and by the large rear engines. The engines are fed with fuel from a massive external tank upon which the Orbiter sits. When in space, the Orbiter, which has discarded its solid rocket boosters, acts like any other rocket in space, held in orbit by maintaining a speed to counter the force of gravity. There is no atmosphere where the Orbiter flies, so there is no friction. This means the wings do not serve their traditional purpose, since there is nothing to "push against." Furthermore, once the Orbiter is inserted into orbit by its rockets, it will continue to travel at 17,500 miles per hour for a long time without the necessity of using additional power.

When it is time for the Orbiter to return to earth, it slows down by turning itself backwards and gravity begins to pull it earthwards at a 25 degree angle. The Orbiter glides to the earth and lands like an airplane on a large runway. By the time it lands, the Orbiter has slowed to a speed of 200 miles/hour. The Orbiter or shuttle slows down as it begins to land because the landing approach follows a large S curve, much like the path taken down a steep mountain by a skier. Furthermore, upon entering the atmosphere, the Orbiter encounters air molecules which cause great friction, which, in turn, slows the speed.

One of the most difficult engineering problems encountered during the design of the Orbiter was to protect it from the tremendous heat generated by friction as it reentered the atmosphere. To help visualize the impact of entering the atmosphere, think of the Orbiter passing through a sheet of paper. The parts that hit the paper first need the greatest protection. Special heat resistant surfaces were developed for these surfaces. The leading edges of the wings and nose of the craft are covered with an extraordinary material called "carbon-carbon." The bottom and edges of the tail fins are covered with black tiles, somewhat less heat resistant than the carbon-carbon material. The remainder of the orbiter has white tiles. These are even less heat resistant but still very effective in protecting the areas to which they are attached.

Once the shuttle has landed, it is transported back to the Kennedy Space Center in Florida, piggy-back, aboard a specially designed 747 so that it can be re-outfitted for its next mission. The large external fuel tank is destroyed during the launch, but the solid rocket boosters parachute to the earth and are recovered from the ocean so that they may be used again for up to 20 launches. The solid rocket boosters are made in many sections which are fitted together at the Kennedy Space Center like a giant puzzle. These sections are sealed together by rubber gaskets called O-rings. Each Orbiter is expected to be re-used up to 100 times. Since it is designed only to achieve earth orbit, the current space shuttle could never make a trip to the moon or other planets. However, the shuttle will contribute to future planetary exploration by serving as a prototype for more advanced vehicles or by bringing astronauts to space stations, from which they will embark to other planets.

GRAVITATION AND BIOLOGY

As humans move out to settle space, the consequences of long-term exposure to less than Earth's gravity must be fully understood. In our deliberations, the Commission has found a serious lack of data regarding the effects on the health of humans living for long periods of time in low-gravity environments.

NASA's experience suggests that the "space sickness" syndrome that afflicts as many as half the astronauts and cosmonauts is fortunately self-limiting. Of continuous concern to medical specialists, however, are the problems of cardiovascular deconditioning after months of exposure to microgravity, the demineralization of the skeleton, the loss of muscle mass and red blood cells, and impairment of the immune response.

Space shuttle crews now routinely enter space for periods of seven to nine days and return with no recognized long-term health problems, but these short-term flights do not permit sufficiently detailed investigations of the potentially serious problems. For example, U.S. medical authorities report that Soviet cosmonauts who returned to Earth in 1984 after 237 days in space emerged from the flight with symptoms that mimicked severe cerebellar disease, or cerebellar atrophy. The cerebellum is the part of the brain that coordinates and smooths out muscle movement, and helps create the proper muscle force for the movement intended. These pioneering cosmonauts apparently required 45 days of Earth gravity before muscle coordination allowed them to remaster simple children's games, such as playing catch, or tossing a ring at a vertical peg.

As little as we know about human adaptation to microgravity, we have even less empirical knowledge of the long-term effects of the one-sixth gravity of the Moon, or the one-third gravity of Mars. We need a vigorous biomedical research program, geared to understanding the problems associated with long-term human spaceflight. Our recommended Variable-g Research Facility in Earth orbit will help the Nation accumulate the needed data to support protracted space voyages by humankind and life on worlds with different gravitational forces. We can also expect valuable new medical information useful for Earth-bound patients from this research.

From: Pioneering the Space Frontier The Report of The National Commision on Space, Bantam Books, 1986.

OUTER SPACE AGREEMENTS

Five U.N. treaties are currently in force regarding activities in space: the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and other Celestial Bodies (1967); the Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space (1968); the Convention on International Liability for Damage Caused by Space Objects (1972); the Convention on Registration of Objects Launched into Outer Space (1976); and the Treaty on Principles Governing Activities on the Moon and Other Celestial Bodies (1979). The major space nations, including the United States and Soviet Union, have ratified all but the last, which is more commonly referred to as the "Moon Treaty." Only five countries have signed and ratified that agreement.

In addition to deliberations at the United Nations, there is an organization called the International Institute of Space Law, which is part of the International Astronautical Federation that provides a forum for discussing space law at its annual meetings.

INTERNATIONAL SPACE YEAR

A specific opportunity for global space cooperation will occur in 1992. Called the International Space Year (ISY), it will take advantage of a confluence of anniversaries in 1992: the 500th anniversary of the discovery of America, the 75th anniversary of the founding of the Union of Soviet Socialist Republics, and the 35th anniversaries of the International Geophysical Year and the launch of the first artificial satellite, Sputnik 1. During this period, it is also expected that the International Geosphere/Biosphere Program will be in progress, setting the stage for other related space activities.

In 1985, Congress approved the ISY concept in a bill that authorizes funding for NASA. The legislation calls on the President to endorse the ISY and consider the possibility of discussing it with other foreign leaders, including the Soviet Union. It directs NASA to work with the State Department and other Government agencies to initiate interagency and international discussions exploring opportunities for international missions and related research and educational activities.

As stated by Senator Spark Matsunaga on the tenth anniversary of the historic Apollo-Soyuz Test Project, July 17, 1985, "An International Space Year won't change the world. But at the minimum, these activities help remind all peoples of their common humanity and their shared destiny aboard this beautiful spaceship we call Earth."

From: Pioneering the Space Frontier The Report of The National Commision on Space, Bantam Books, 1986.

PROTECTING THE SPACE ENVIRONMENT FROM DEBRIS

What goes up must come down—even in Earth orbit! The difference in space is that it can take millions of years for objects to be pulled back to Earth by friction with Earth's atmosphere, depending on how close they are to Earth. An object 100 miles above Earth will return in a matter of days, while objects in geostationary orbit will take millions of years to reenter.

Since the dawn of the Space Age, thousands of objects with a collective mass of millions of pounds have been deposited in space. While some satellites and pieces of debris are reentering, others are being launched, so the space debris population remains constant at approximately 5,000 pieces large enough to be tracked from Earth (thousands more are too small to be detected). This uncontrolled space population presents a growing hazard of reentering objects and in-space collisions.

As objects reenter, they usually burn up through the heat of friction with Earth's atmosphere, but large pieces may reach the ground. This can constitute a danger to people and property, although there is no proof that anyone has ever been struck by a piece of space debris. There are numerous cases of such debris reaching the ground, however, including the reentry of the U.S. Skylab over Australia in 1979, and the unexpected reentry of two Soviet nuclear reactor powered satellites in 1978 and 1983.

The hazard of in-space collisions is created both by multiple collisions between pieces of debris and by intentional or unintentional explosions or fragmentations of satellites. When space objects collide with each other or explode, thousands of smaller particles are created, increasing the probability of further collisions among themselves and with spacecraft. A spacecraft is now more likely to be damaged by space debris than by small micrometeorites. For large, long-life orbital facilities, such as space stations and spaceports, the collision probabilities will become serious by the year 2000, requiring bumper shields or other countermeasures, and more frequent maintenance.

All spacefaring nations should adopt preventive measures to minimize the introduction of new uncontrolled and long-lived debris into orbit. Such countermeasures include making all pieces discarded from spacecraft captive, deorbiting spent spacecraft or stages, adjusting the orbits of transfer stages so that rapid reentry is assured due to natural disturbances, and designating long-life disposal orbits for high altitude spacecraft. The increasing hazard of space debris must be halted and reversed.

From: Pioneering the Space Frontier The Report of The National Commision on Space, Bantam Books, 1986.

Typical Student Questions
and
Discussion

THE SPACE SHUTTLE

How long could you survive in space without a space suit?

As long as you could hold your breath. Once you exhale, there is nothing to breathe so you would suffocate.

What is a space suit used for?

The space suit serves several functions. First, it provides oxygen for the astronaut to breathe. Second, it serves as a thermal protector from the radiation in space. Finally, it provides a pressurized environment which is similar to the atmospheric pressure we experience here on Earth.

If you didn't have a space suit on while in space, what would happen to you? Would you "explode" like a balloon because of the lack of pressure?

It is difficult to say because it has never happened to anyone. Scientists speculate that you would not "explode", but that it would be very uncomfortable. It would be similar to the sensation a deep sea diver experiences when he dives thousands of feet under water.

Is there any sound aboard the Space Shuttle?

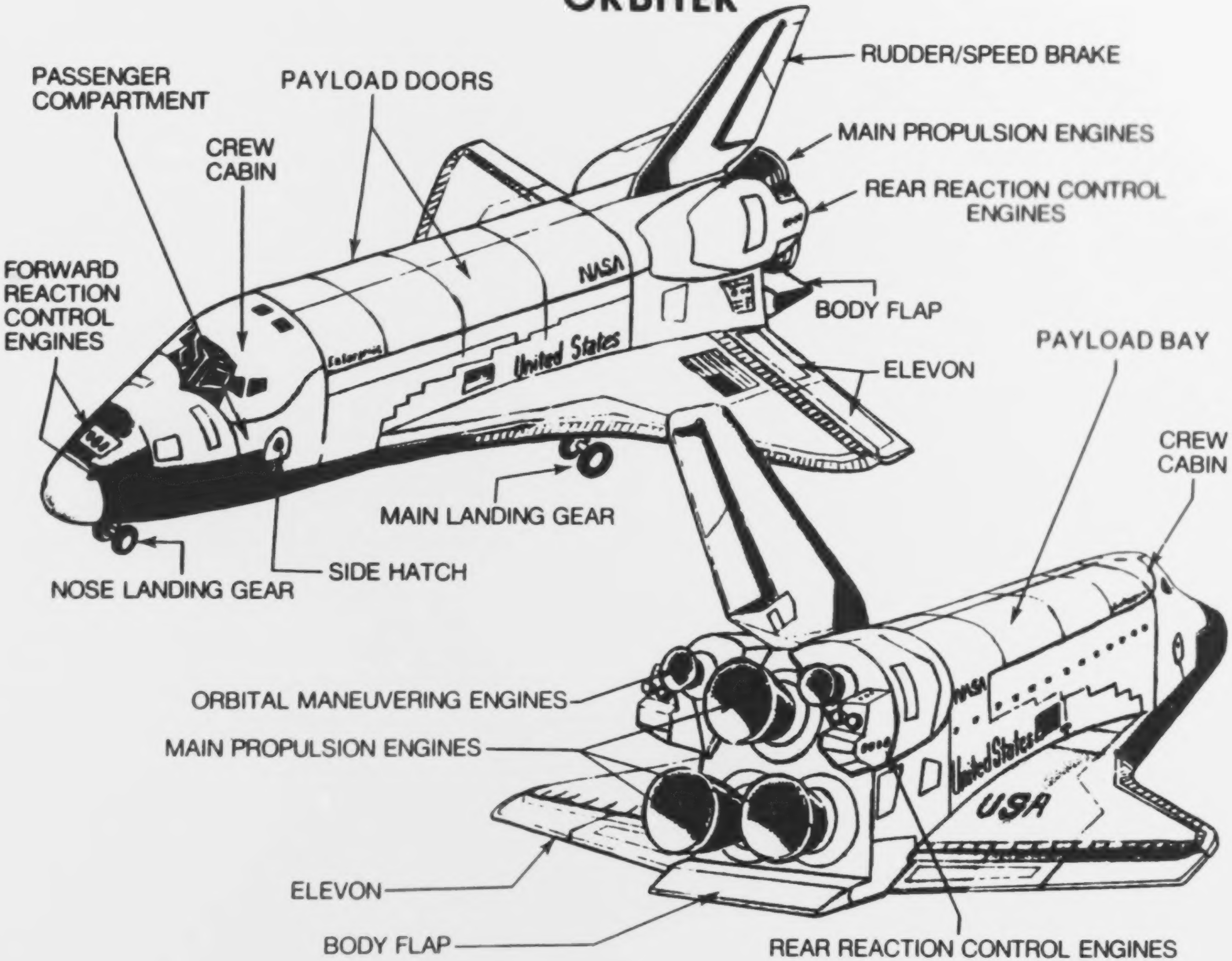
Yes. Since the cabin of the shuttle is filled with air for the astronauts to breathe, there is a medium for sound waves to travel through. The astronauts can hear each other speak as well as other sounds on board.

Can you have a pregnant astronaut in space?

Yes. There is no evidence so far to prove that the normal human functions are interrupted by the effects of weightlessness.

COMPONENTS OF THE SHUTTLE SYSTEM

ORBITER

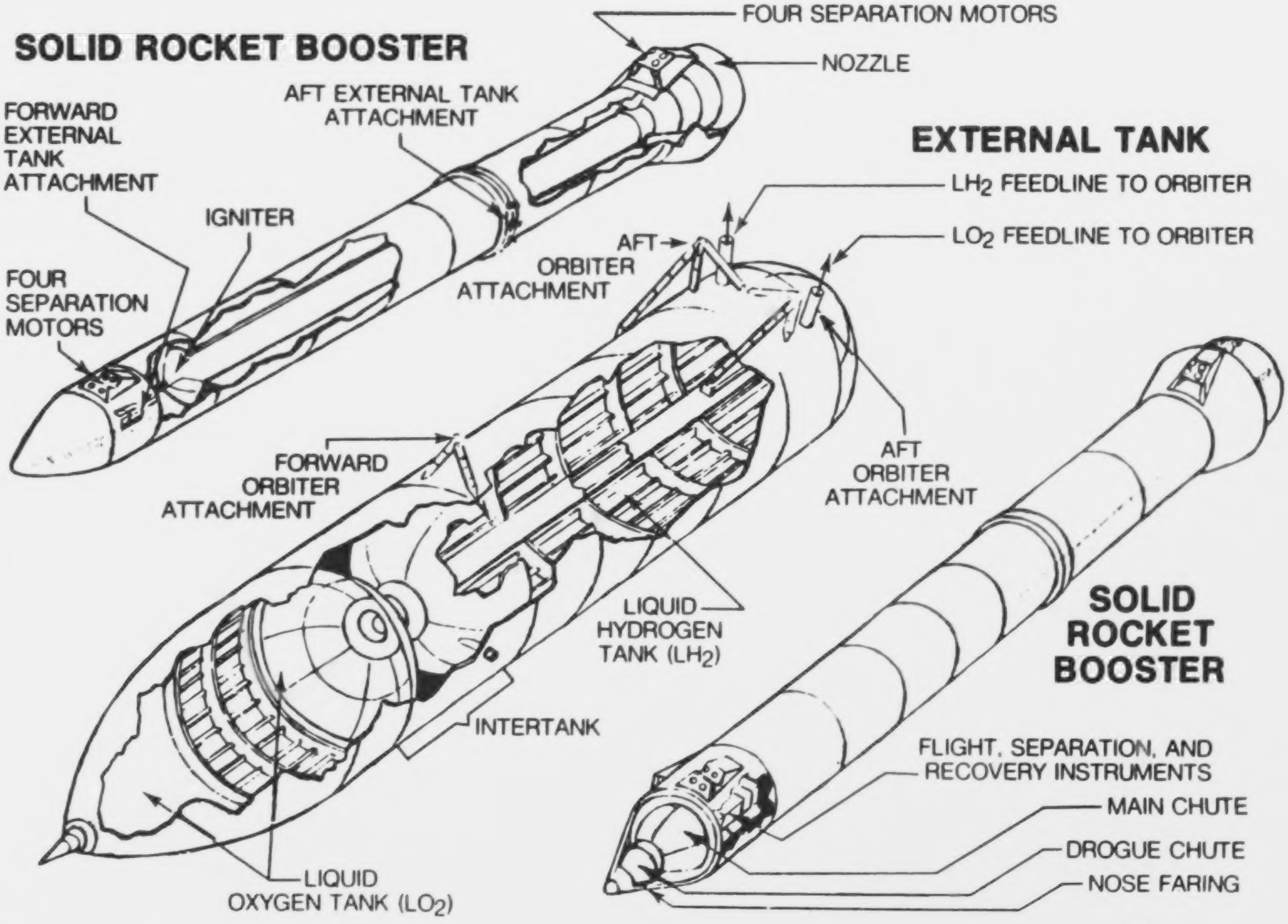


From: Civil Air Patrol Charts, Maxwell Air Force Base.

Regional Math Network • Harvard Graduate School of Education • Harvard University

Fact Book 39

SOLID ROCKET BOOSTERS AND EXTERNAL TANK


SOLID ROCKET BOOSTER
FOUR SEPARATION MOTORS
NOZZLE
AFT EXTERNAL TANK ATTACHMENT
FORWARD EXTERNAL TANK ATTACHMENT
IGNITER
FOUR SEPARATION MOTORS
EXTERNAL TANK
LH_2 FEEDLINE TO ORBITER
LO_2 FEEDLINE TO ORBITER
AFT
ORBITER ATTACHMENT
AFT ORBITER ATTACHMENT
FORWARD ORBITER ATTACHMENT
LIQUID HYDROGEN TANK (LH_2)
INTERTANK
LIQUID OXYGEN TANK (LO_2)
SOLID ROCKET BOOSTER
FLIGHT, SEPARATION, AND RECOVERY INSTRUMENTS
MAIN CHUTE
DROGUE CHUTE
NOSE FARING

Fact Book
40

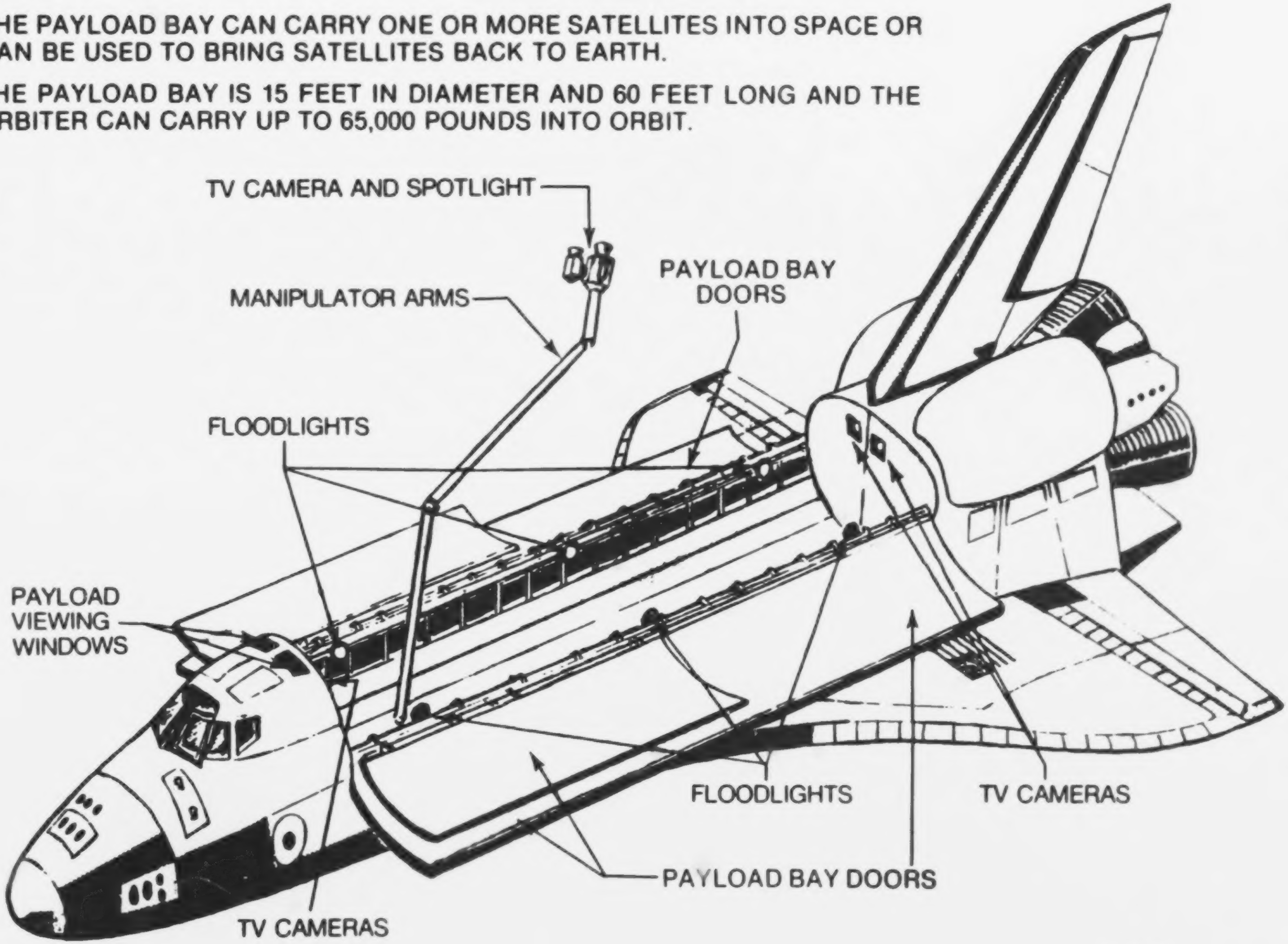
From: Civil Air Patrol Charts, Maxwell Air Force Base.

Regional Math Network • Harvard Graduate School of Education • Harvard University

PAYLOAD BAY

THE PAYLOAD BAY CAN CARRY ONE OR MORE SATELLITES INTO SPACE OR CAN BE USED TO BRING SATELLITES BACK TO EARTH.

THE PAYLOAD BAY IS 15 FEET IN DIAMETER AND 60 FEET LONG AND THE ORBITER CAN CARRY UP TO 65,000 POUNDS INTO ORBIT.

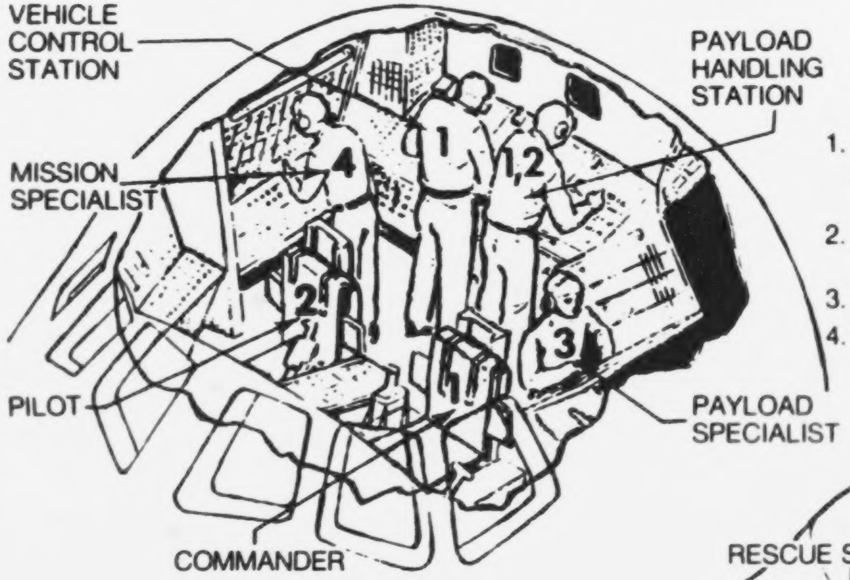


From: Civil Air Patrol Charts, Maxwell Air Force Base.
Regional Math Network • Harvard Graduate School of Education • Harvard University

From: Civil Air Patrol Charts, Maxwell Air Force Base.

Regional Math Network • Harvard Graduate School of Education • Harvard University

CREW AND PASSENGER COMPARTMENTS



CREW

★ LAUNCH SEATS STOWED UNDER COMMANDER'S SEAT WHILE IN ORBIT.

1. SHUTTLE COMMANDER: ALSO MANS THE VEHICLE CONTROL STATION OR THE PAYLOAD HANDLING STATION IN ORBIT.
2. PILOT: ALSO MANS THE PAYLOAD HANDLING STATION IN ORBIT.
3. PAYLOAD SPECIALIST ★
4. MISSION SPECIALIST ★

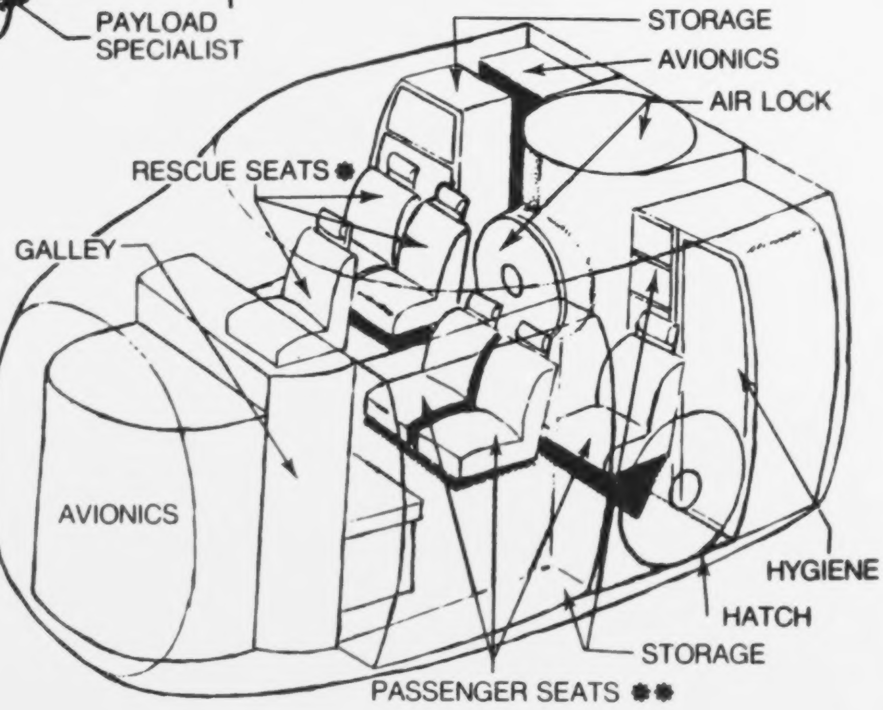
✱ PASSENGER COMPARTMENT AND CREW LIVING QUARTERS.

BUNKS REPLACE RESCUE SEATS ON FLIGHTS NOT INVOLVING RESCUE.

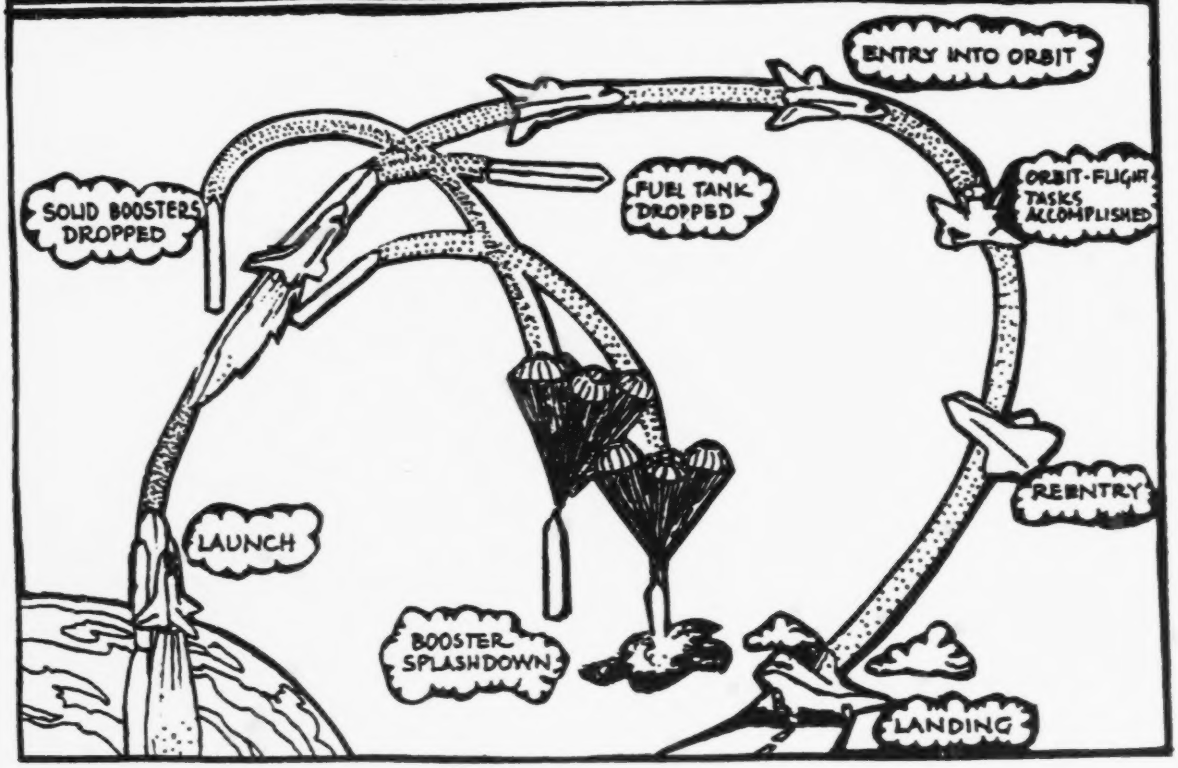
✱✱ PASSENGER SEATS NOT CARRIED ON FLIGHTS NOT INVOLVING PASSENGERS.

SHOWER AND LAVATORY ARE IN THE HYGIENE AREA.

AIRLOCK PROVIDES ENTRY INTO THE PAYLOAD BAY.



SPACE SHUTTLE - FROM LAUNCH TO LANDING

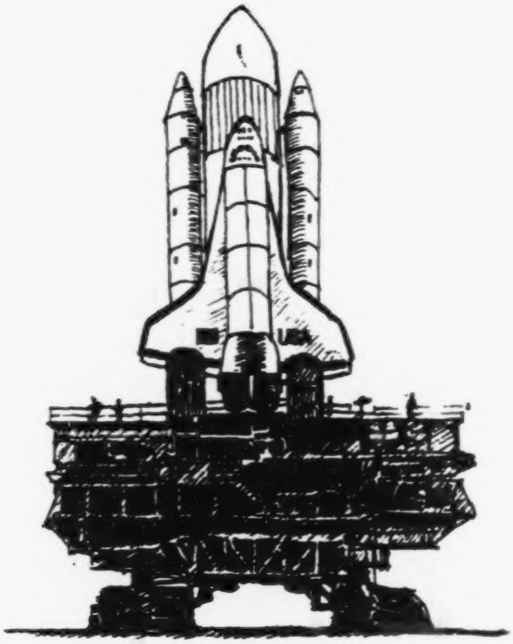


THE FLIGHT

	Time (sec)	Altitude	Velocity
Ignition	0.0	(194')	
Lift-off	0.2	(194')	
Mach I	53	25,398'	1,063 (ref)
Maximum dynamic pressure	54	26,328'	1,080
Solid Booster Seperation	72	27 mi.	3200 mph
SRB jettison	131.7	165,604'	4193 (ref)
Normal 3 g limit	454	397,230'	20,119 (inertial)
MECO command	512.4	386,322'	25,591
External tank separation	529.9	388,872'	25,666
OMS1 ignition	632.4	414,206'	25,638
OMS 1 cutoff	721.1	433,666'	25,780
OMS 2 ignition	2640.4	794,227'	25,336
OMS 2 entry into orbit	2717.4	795,865'	25,471
Orbiter operations		100-600 mi.	
Re-entry		76 mi.	17,400
Landing		0	200

RE-ENTR

	Altitude	Speed
Entering the atmosphere:	48 mi	17,670 mph
(Temperature at re-entry: 2300° F)	20.5 mi	2,976 mph
	458 mi	1,064 mph
	9.3 mi	458 mph
	0 mi	217 mph



THE SHUTTLE SYSTEM

ITS SIZE:

	Shuttle System	Cargo Bay	Orbiter	External Tank	Solid Boosters (2)	Payload Arm
Length	184'	60'	122'	154'	149'	60'
Wing Span	78'	-	78'	-	-	-
Height	76'	-	57'	28.6'	13'	-
Weight at Lift-off	4,457,825 lbs.	(65,000 lbs.)*	150,000 lbs.**	1,638,535 lbs.	743,000 lbs.***	-
at return	514,000 lbs.	-	150,000 lbs.**	78,000 lbs.	193,000 lbs.***	-
Thrust	6,925,000	-	3@375,000	-	2,900,000 each	-
Diameter	-	15'	15'	28.6'	12.2'	-

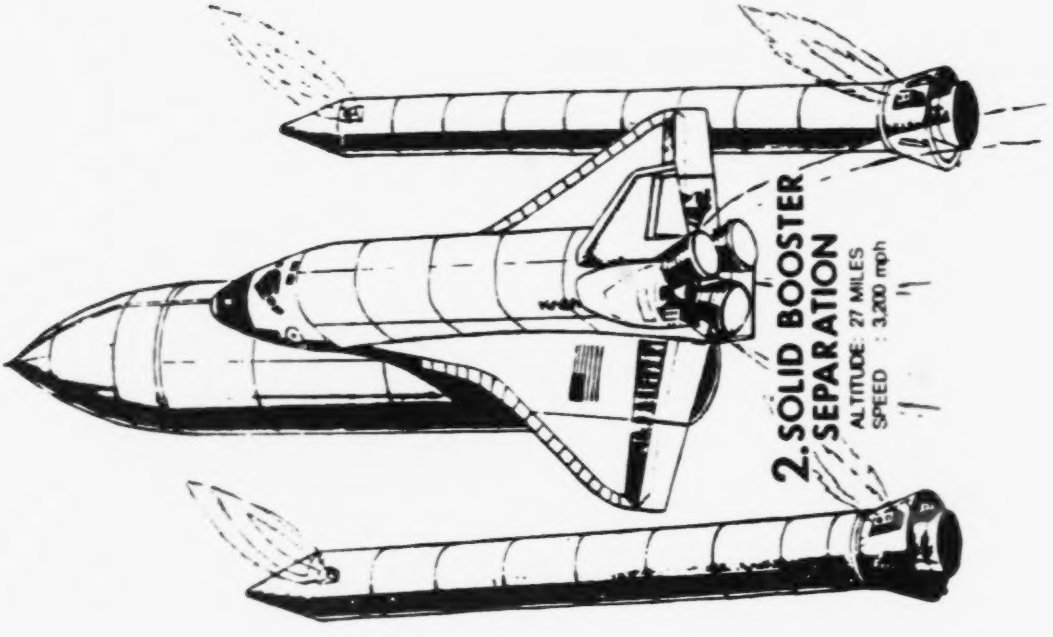
* Potential Capacity
** Empty
*** Each

Some interesting facts:

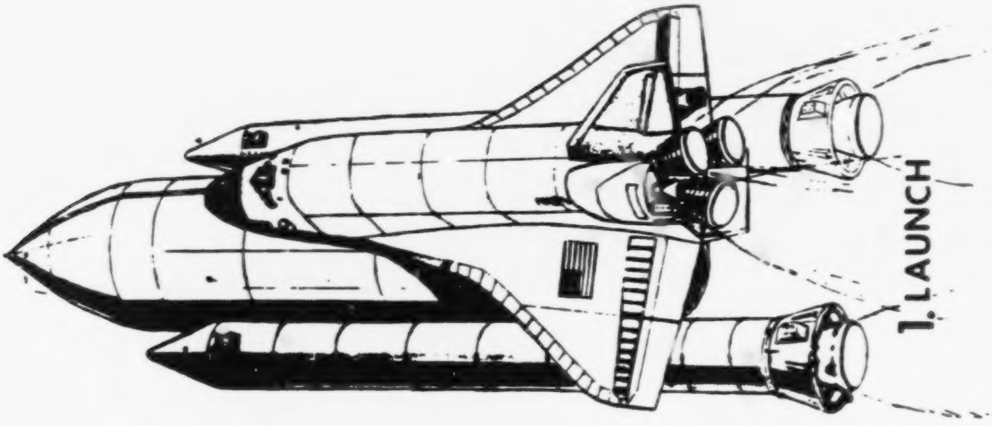
- Volume of crew's quarters 2,625 cu. ft.
- The orbiter is similar in size to a DC-9 jet.
- The landing runway at Kennedy Space Center is 2.83 mi. long x 56 mi. wide.
- The solid rocket boosters can be used 20 times.
- The orbiter is reusable for 100 missions.
- The length of a mission can be up to 30 days.
- The number of crew/passengers on the orbiter is 7.
- The external tank is filled with liquid hydrogen and liquid oxygen. (101 tons liquid hydrogen, 603 tons liquid oxygen). The external tank is used only once.
- Maximum gravity forces experienced is 3G's.
- Always takes off from East Coast (over water for safety) heading East (to take advantage of earth's rotation.)
- Countdown begins three days before actual lift-off.
- No human photographers are allowed within 3.5 miles of the launch pad.
- The Crawler Transporter is 131' x 114'.

From: Civil Air Patrol Charts, Maxwell Air Force Base.

STAGES
OF
SHUTTLE MISSION

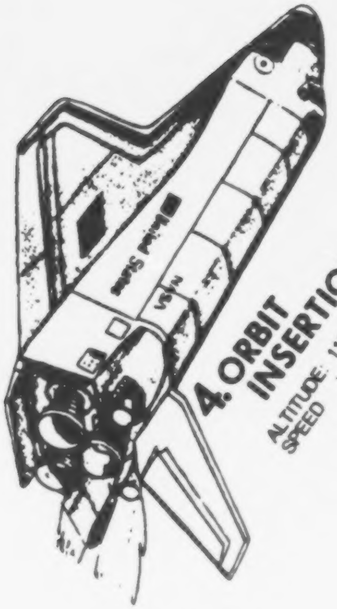


2. SOLID BOOSTER SEPARATION
ALTITUDE: 27 MILES
SPEED : 3,200 mph



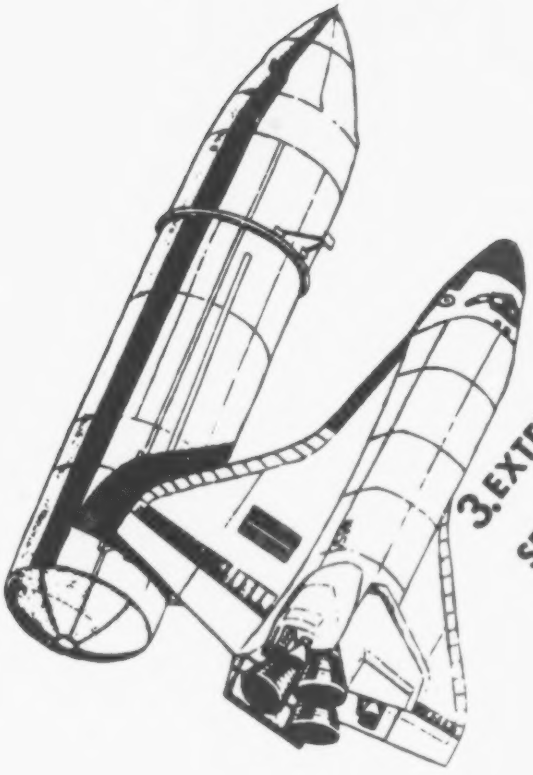
1. LAUNCH

From: Civil Air Patrol Charts, Maxwell Air Force Base



4. ORBIT INSERTION

ALTITUDE: 115 MILES
SPEED : 17,600 mph

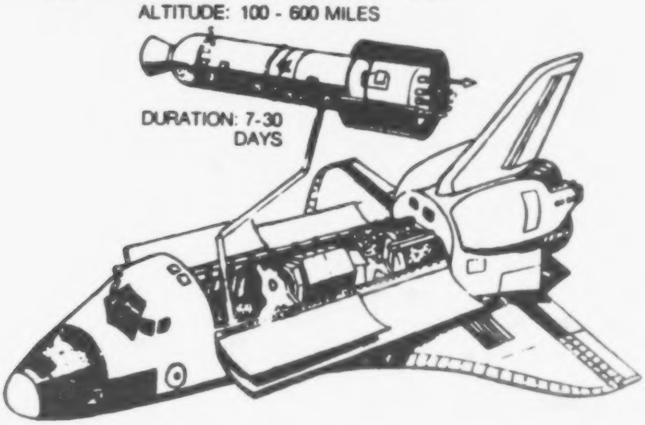


3. EXTERNAL TANK SEPARATION

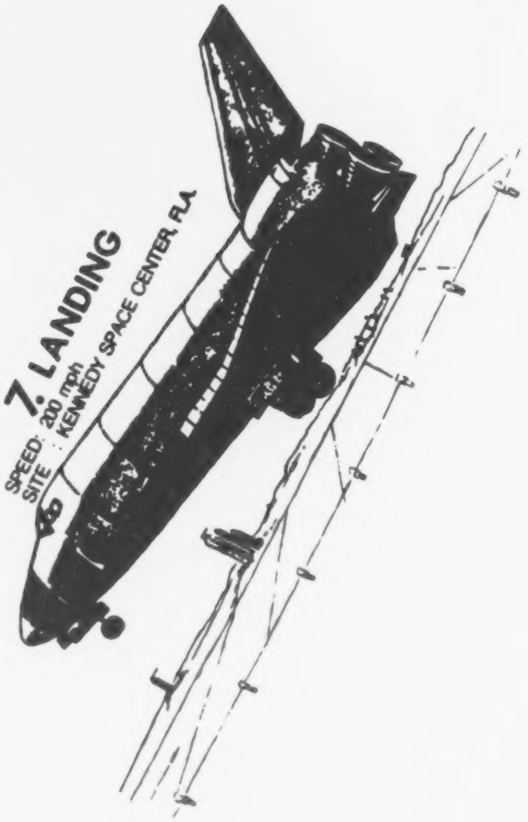
ALTITUDE 75 MILES
SPEED 16,500 mph

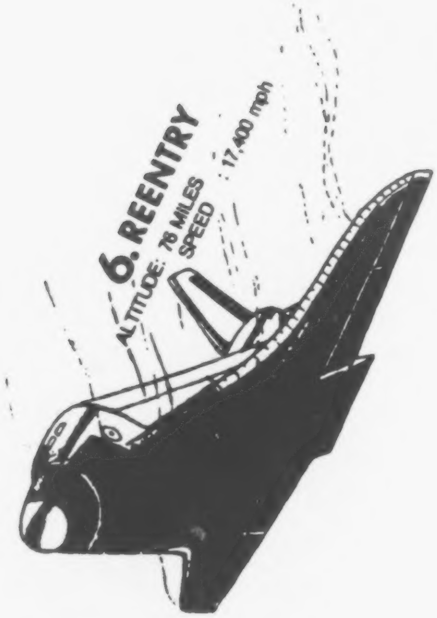
From: Civil Air Patrol Charts, Maxwell Air Force Base.

5. ORBITAL OPERATIONS

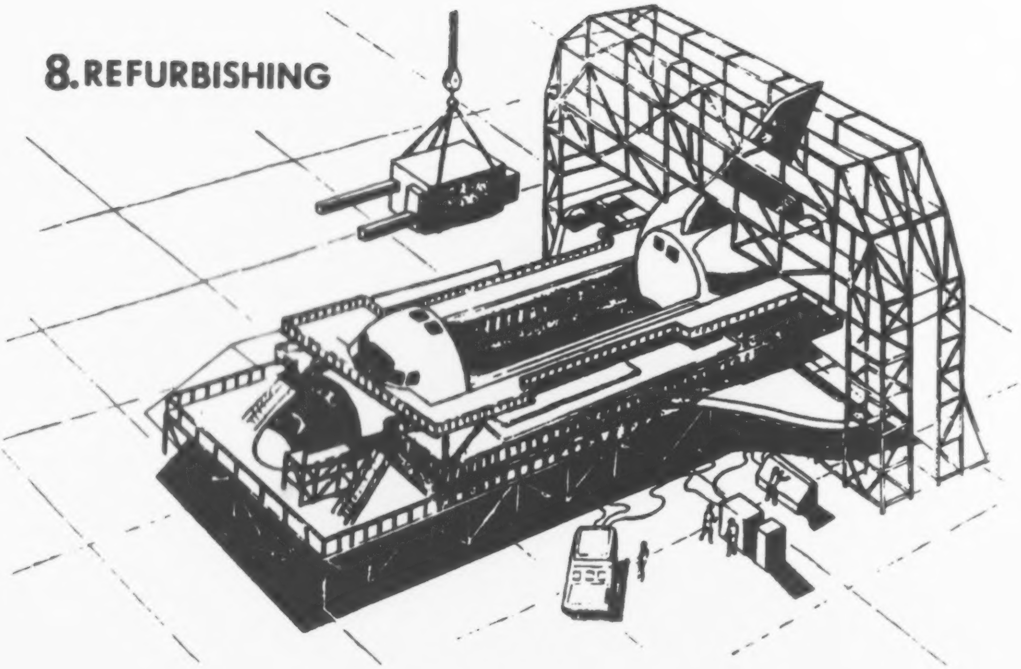


From: Civil Air Patrol Charts, Maxwell Air Force Base.


7. LANDING
SPEED : 200 mph
SITE : KENNEDY SPACE CENTER, FLA.

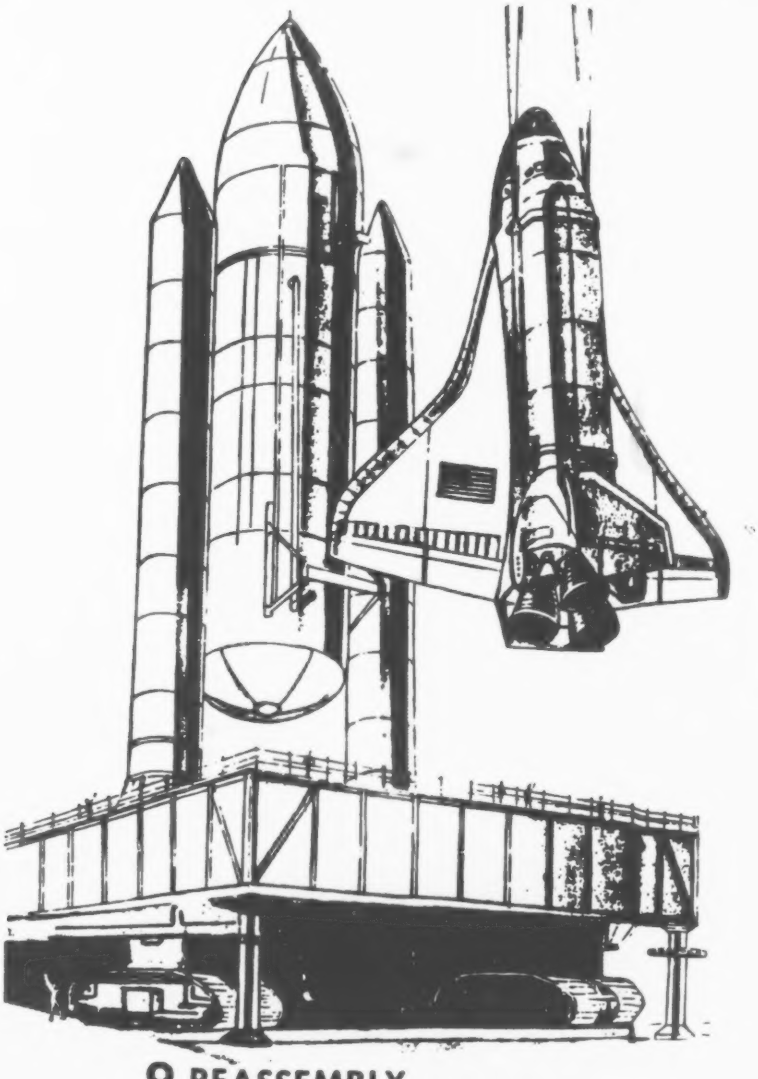


From: Civil Air Patrol Charts, Maxwell Air Force Base.



8. REFURBISHING

From: Civil Air Patrol Charts, Maxwell Air Force Base.



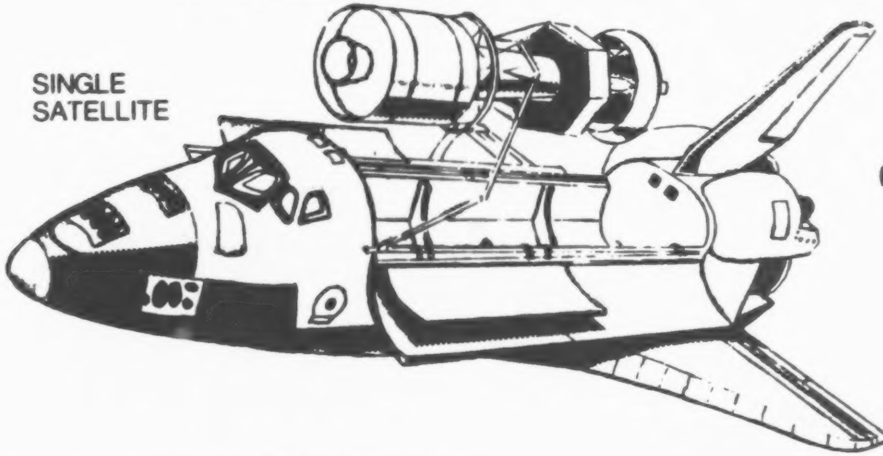
9. REASSEMBLY

From: Civil Air Patrol Charts, Maxwell Air Force Base.

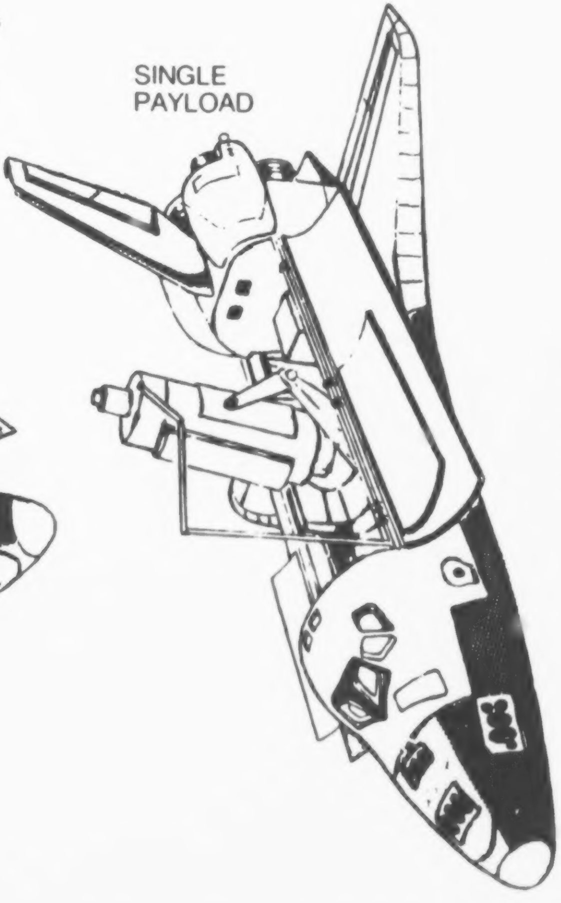
DELIVERY INTO EARTH ORBIT

THIS IS THE PRIMARY MISSION FOR THE SPACE SHUTTLE. THE ORBITER CAN DELIVER UP TO 65,000 POUNDS INTO EARTH ORBIT. THIS MAY BE ONE LARGE SATELLITE OR UP TO FIVE SMALLER ONES.

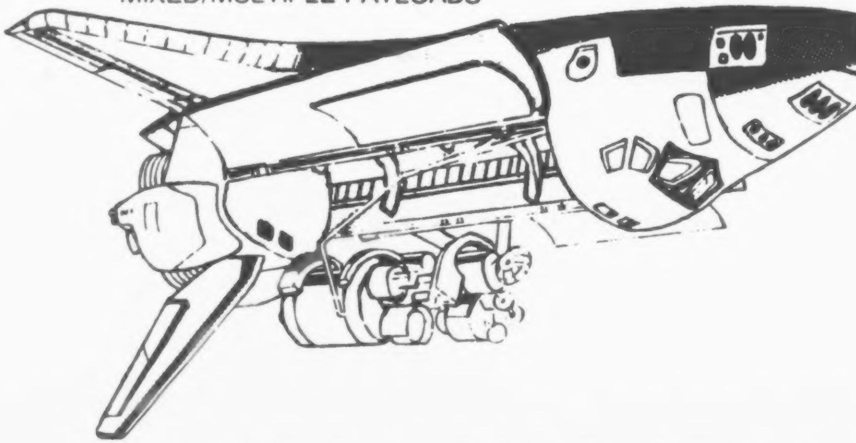
SINGLE SATELLITE



SINGLE PAYLOAD



MIXED/MULTIPLE PAYLOADS



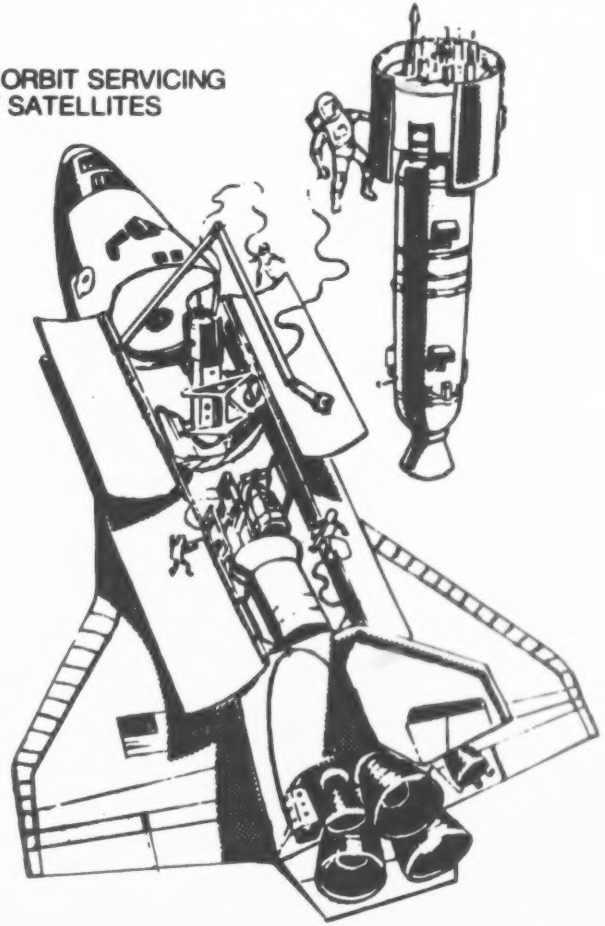
THE ORBITER HAS A THREE-DIMENSIONAL MANEUVERING CAPABILITY BY WHICH IT CAN ESTABLISH ITSELF IN ANY DESIRED POSITION IN A SPECIFIC ORBIT OR CHANGE ORBITS.

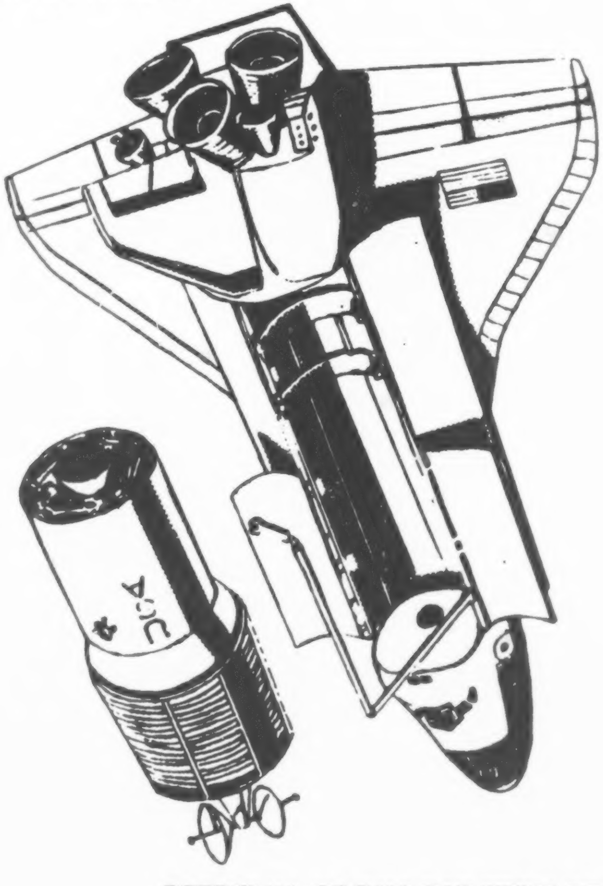
From: Civil Air Patrol Charts, Maxwell Air Force Base

RETRIEVAL OR IN-ORBIT SERVICING OF SATELLITES

THE SPACE SHUTTLE IS MORE THAN JUST A TRANSPORT VEHICLE. THE ORBITER CAN RETRIEVE PAYLOADS FROM ORBIT FOR RETURN TO EARTH. ALSO, WHEREVER POSSIBLE SATELLITES WILL BE "PLUCKED" OUT OF SPACE, REPAIRED, AND RETURNED TO ORBIT.

IN-ORBIT SERVICING OF SATELLITES





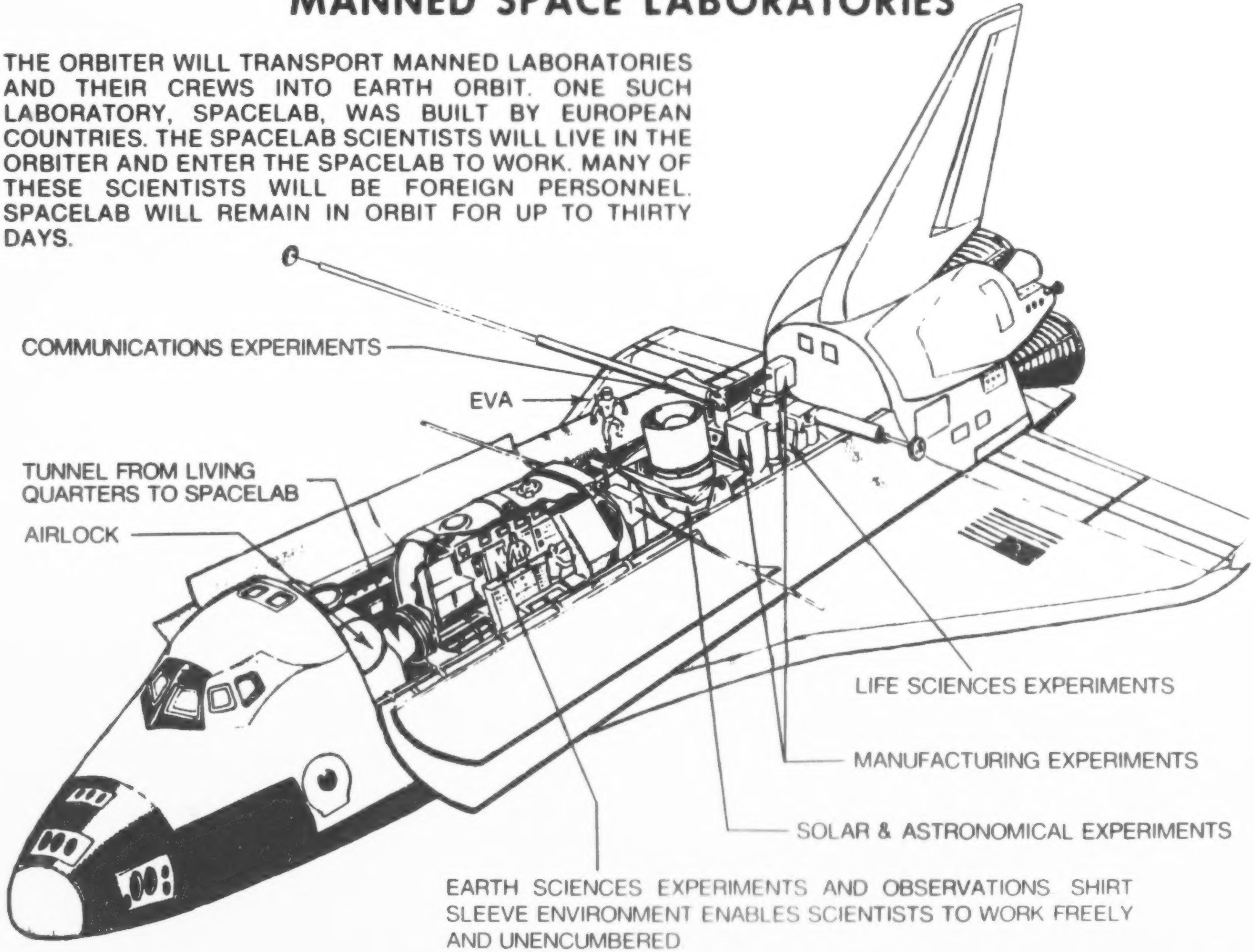
RETRIEVAL OF PAYLOAD FROM ORBIT FOR RETURN TO EARTH.

From: Civil Air Patrol Charts, Maxwell Air Force Base.

Regional Math Network • Harvard Graduate School of Education • Harvard University

MANNED SPACE LABORATORIES

THE ORBITER WILL TRANSPORT MANNED LABORATORIES AND THEIR CREWS INTO EARTH ORBIT. ONE SUCH LABORATORY, SPACELAB, WAS BUILT BY EUROPEAN COUNTRIES. THE SPACELAB SCIENTISTS WILL LIVE IN THE ORBITER AND ENTER THE SPACELAB TO WORK. MANY OF THESE SCIENTISTS WILL BE FOREIGN PERSONNEL. SPACELAB WILL REMAIN IN ORBIT FOR UP TO THIRTY DAYS.


COMMUNICATIONS EXPERIMENTS
EVA
TUNNEL FROM LIVING QUARTERS TO SPACELAB
AIRLOCK
LIFE SCIENCES EXPERIMENTS
MANUFACTURING EXPERIMENTS
SOLAR & ASTRONOMICAL EXPERIMENTS
EARTH SCIENCES EXPERIMENTS AND OBSERVATIONS. SHIRT SLEEVE ENVIRONMENT ENABLES SCIENTISTS TO WORK FREELY AND UNENCUMBERED

From: Civil Air Patrol Charts, Maxwell Air Force Base.

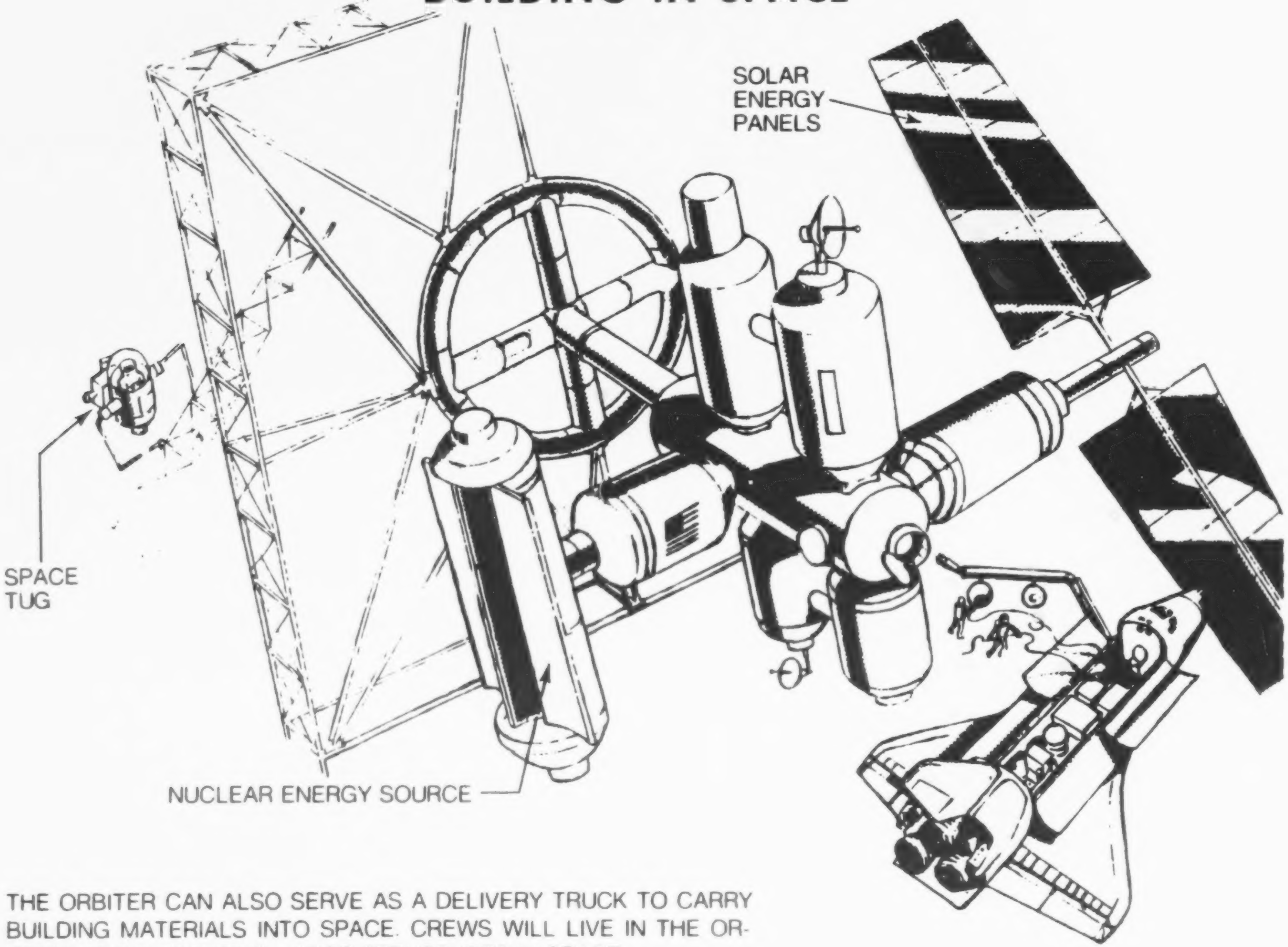
Regional Math Network • Harvard Graduate School of Education • Harvard University

Fact Book
53

From: Civil Air Patrol Charts, Maxwell Air Force Base.

Regional Math Network • Harvard Graduate School of Education • Harvard University

BUILDING IN SPACE



THE ORBITER CAN ALSO SERVE AS A DELIVERY TRUCK TO CARRY BUILDING MATERIALS INTO SPACE. CREWS WILL LIVE IN THE ORBITER WHILE ERECTING LARGE STRUCTURES IN SPACE.

HISTORY OF MANNED SPACE MISSIONS

Program [1]	Date(s)/Recovery Ship [2]	Crew	Mission Duration [3]	Remarks [4]
MERCURY				
Mercury Redstone 3 (Freedom 7)	May 5, 1961 Lake Champlain (A)	Navy Comdr. Alan B. Shepard, Jr.	0:15:22	suborbital
Mercury Redstone 4 (Liberty Bell 7)	July 21, 1961 Randolph (A)	USAF Maj. Virgil I. Grissom	0:15:37	suborbital
Mercury Atlas 6 (Friendship 7)	Feb. 20, 1962 Noa (A)	Marine Lt. Col. John H. Glenn	4:55:23	3 orbits
Mercury Atlas 7 (Aurora 7)	May 24, 1962 Pierce (A)	Navy Lt. Comdr. Scott Carpenter	4:56:05	3 orbits
Mercury Atlas 8 (Sigma 7)	Oct. 3, 1962 Kearsarge (P)	Navy Comdr. Walter M. Schirra, Jr.	9:13:11	6 orbits
Mercury Atlas 9 (Faith 7)	May 15-16, 1963 Kearsarge (P)	USAF Maj. L. Gordon Cooper	34:19:49	22 orbits
GEMINI				
Gemini 3 (Molly Brown)	March 23, 1965 Intrepid (A)	USAF Maj. Virgil I. Grissom Navy Lt. Comdr. John W. Young	4:53	3 orbits
Gemini 4	June 3-7, 1965 Wasp (A)	USAF Majors James A. McDivitt and Edward H. White, II	97:56	62 orbits; first U.S. EVA (White)
Gemini 5	Aug. 21-29, 1965 Lake Champlain (A)	USAF Lt. Col. L. Gordon Cooper Navy Lt. Comdr. Charles Conrad, Jr.	190:55	120 orbits
Gemini 7	Dec. 4-18, 1965 Wasp (A)	USAF Lt. Col. Frank Borman Navy Comdr. James A. Lovell, Jr.	330:35	Longest Gemini flight; rendezvous target for Gemini 6; 206 orbits
Gemini 6	Dec. 15-16, 1965 Wasp (A)	Navy Capt. Walter M. Schirra, Jr. USAF Maj. Thomas P. Stafford	25:51	Rendezvoused within 1 ft. of Gemini 7; 16 orbits
Gemini 8	Mar. 16, 1966 L. F. Mason (P)	Civilian Neil A. Armstrong USAF Maj. David R. Scott	10:41	Docked with unmanned Agena 8; 7 orbits
Gemini 9A	June 3-6, 1966 Wasp (A)	USAF Lt. Col. Thomas P. Stafford Navy Lt. Comdr. Eugene A. Cernan	72:21	Rendezvous (3) with Agena 9; one EVA; 44 orbits
Gemini 10	July 18-21, 1966 Guadalcanal (A)	Navy Comdr. John W. Young USAF Maj. Michael Collins	70:47	Docked with Agena 10; rendezvoused with Agena 8; two EVAs; 43 orbits

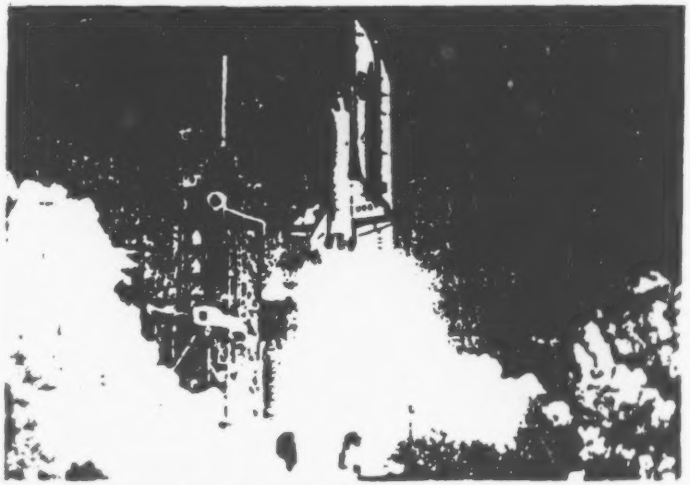
NOTES:
1. Names in parentheses are crew names for spacecraft and Lunar Modules
2. (A) or (P) denotes Atlantic or Pacific Ocean splashdown
3. Hours and minutes, except for Skylab
4. EVA refers to extravehicular activity, or activity outside the spacecraft; LM refers to Lunar Module

Gemini 11	Sept. 12-15, 1966 Guam (A)	Navy Comdr. Charles Conrad, Jr. Navy Lt. Comdr. Richard F. Gordon, Jr.	71:17	Docked with Agena 11 twice; first tethered flights; two EVAs; highest altitude in Gemini program; 853 miles; 44 orbits
Gemini 12	Nov. 11-15, 1966 Wasp (A)	Navy Capt. James A. Lovell, Jr. USAF Maj. Edwin E. Aldrin, Jr.	94:35	Three EVAs total 5 hrs. 30 min.; 59 orbits
APOLLO				
Apollo 1	Jan. 27, 1967	USAF Lt. Col. Virgil I. Grissom USAF Lt. Col. Edward H. White, II Navy Lt. Comdr. Roger Chafee		Planned as first manned Apollo Mission; fire during ground test on 1/27/67 took lives of astronauts; posthumously designated as Apollo 1.[5]
Apollo 4	Nov. 4, 1967 Bennington (P)	Unmanned	9:37	First flight of Saturn V launch vehicle. Placed unmanned Apollo command and service module in Earth orbit.
Apollo 5	Jan. 22, 1968	Unmanned	7:50	Earth orbital flight test of unmanned Lunar Module. Not recovered
Apollo 6	April 4, 1968 Okinawa (P)	Unmanned	9:57	Second unmanned test of Saturn V and Apollo
Apollo 7	Oct. 11-22, 1968 Essex (A)	Navy Capt. Walter M. Schirra, Jr. USAF Maj. Donn Eisele Civilian Walter Cunningham	260:08:45	Tested Apollo Command Module in Earth orbit; 163 orbits
Apollo 8	Dec. 21-27, 1968 Yorktown (P)	USAF Col. Frank Borman Navy Capt. James A. Lovell, Jr. USAF Lt. Col. William Anders	147:00:11	First manned Saturn V launch; 10 lunar orbits
Apollo 9 (Gumdrop and Spider)	March 3-13, 1969 Guadalcanal (A)	USAF Col. James A. McDivitt USAF Col. David R. Scott Civilian Russell L. Schweickart	241:00:53	Earth orbital mission; first manned flight of LM; two EVAs total 2 hrs. 8 min.; 151 orbits
Apollo 10 (Charlie Brown and Snoopy)	May 18-26, 1969 Princeton (P)	USAF Col. Thomas P. Stafford Navy Comdr. John W. Young Navy Comdr. Eugene E. Cernan	192:03:23	31 lunar orbits; LM descended to within nine miles of lunar surface
Apollo 11 (Columbia, Eagle)	July 16-24, 1969 Hornet (P)	Civilian Neil Armstrong USAF Lt. Col. Michael Collins USAF Col. Edwin E. Aldrin, Jr.	195:18:35	First manned lunar landing; Sea of Tranquility; one lunar EVA 2 hrs. 48 min.; 46 lbs. lunar samples
Apollo 12 (Yankee Clipper and Intrepid)	Nov. 14-24, 1969 Hornet (P)	Navy Comdr. Charles Conrad, Jr. Navy Comdr. Richard F. Gordon, Jr. Navy Comdr. Alan L. Bean	244:36:25	Landed Ocean of Storms; two lunar EVAs total 7 hrs. 46 min. 75 lbs. samples

NOTES: 5. There were no missions designated as Apollo 2 and Apollo 3

Apollo 13 (Odyssey and Aquarius)	April 11-17, 1970 Iwo Jima (P)	Navy Capt. James A. Lovell, Jr. Civilian Fred W. Haise, Jr. Civilian John L. Swigert, Jr.	142:54:41	Lunar landing aborted after oxygen tank ruptured; safe recovery
Apollo 14 (Kitty Hawk and Antares)	Jan. 31-Feb 9, 1971 New Orleans (P)	Navy Capt. Alan B. Shepard, Jr. USAF Maj. Stuart A. Roosa Navy Comdr. Edgar D. Mitchell	216:02:01	Landed Fra Mauro; two lunar EVAs total 9 hrs. 23 min.; 94 lbs. samples
Apollo 15 (Endeavour and Falcon)	July 26-Aug. 7, 1971 Okinawa (P)	USAF Col. David R. Scott USAF Lt. Col. James B. Irwin USAF Maj. Alfred M. Worden	295:12:00	Landed Hadley Apennine; three lunar EVAs total 18 hrs. 46 min.; 169 lbs. samples
Apollo 16 (Casper and Orion)	April 16-27, 1972 Ticonderoga (P)	Navy Capt. John W. Young Navy Lt. Comdr. Thomas K. Mattingly, II USAF Lt. Col. Charles M. Duke, Jr.	265:51:06	Landed Descartes highlands; three lunar EVAs total 20 hrs. 14 min., 213 lbs. samples
Apollo 17 (America and Challenger)	Dec. 7-19, 1972 Ticonderoga (P)	Navy Capt. Eugene A. Cernan Navy Comdr. Ronald E. Evans Civilian Harrison H. Schmitt (Ph. D.)	301:51:59	Landed Taurus-Littrow; three lunar EVAs total 22 hrs. 4 min.; 243 lbs. samples
SKYLAB				
Skylab 1	Launched May 14, 1973	Unmanned	Re-entered atmosphere 7-11-79 on orbit 34,981	100-ton space station visited by three crews
Skylab 2	May 25-June 22, 1973 Ticonderoga (P)	Navy Capt. Charles Conrad, Jr. Navy Comdr. Paul J. Weitz Navy Comdr. Joseph P. Kerwin (M. D.)	28 days 49 min. 49 sec.	Repaired Skylab; 404 orbits; 392 experiment hours; three EVAs total 5 hrs. 34 min.
Skylab 3	July 28-Sept. 25, 1973 New Orleans (P)	Navy Capt. Alan L. Bean Marine Maj. Jack R. Lousma Civilian Owen K. Garriott (Ph. D.)	59 days 11 hrs. 9 min. 4 sec.	Performance maintenance, 858 orbits; 1,081 experiment hours; three EVAs total 13 hrs. 42 min.
Skylab 4	Nov. 16, 1973-Feb. 8, 1974 New Orleans (P)	Marine Lt. Col. Gerald P. Carr USAF Lt. Col. William R. Pogue Civilian Edward G. Gibson (Ph. D.)	84 days 1 hr. 15 min. 31 sec.	Observed Comet Kohoutek; 1,214 orbits; 1,563 experiment hours; four EVAs total 22 hrs. 25 min.
ASTP				
Apollo Soyuz Test Project	July 15, 1975-July 24, 1975 New Orleans (P)	USAF Brig. Gen. Thomas P. Stafford Civilian Vance D. Brand Civilian Donald K. Slayton	9 days 1 hr. 28 min. 24 sec.	Apollo docked with Soviet Soyuz spacecraft[6] July 17; separated July 19

NOTES: 6. Flown by Cosmonauts Aleskey A. Leonov and Valeriy N. Kubasov; mission duration 5 days, 22 hours, 30 minutes, 54 sec.



First (STS-1) liftoff of the Space Shuttle, April 12, 1981.

THE FUTURE OF MANNED SPACE FLIGHT

The 2-million kilogram (4.5 million pound) Space Shuttle is the first vehicle designed to carry both crew and large unmanned applications and scientific spacecraft into orbit. The primary function of prior manned missions was the scientific exploration of the space environment, or the surface of the Moon. Large spacecraft, such as the many geosynchronous orbit communications and weather satellites, planetary explorers, or scientific research probes, were launched on unmanned vehicles. The Space Shuttle combines the weightlifting capacity of the largest unmanned launchers with the unmatched ability of an on-the-spot human being to make decisions and take actions.

No machine yet built can equal a trained astronaut at problem-solving in space, as the recovery and eventual success of the Skylab program amply demonstrated. Shuttle astronauts have repaired a satellite in space and recovered others for more extensive repairs on the ground.

The Space Shuttle can take up to seven crew members—men and women—into low Earth orbit. It has a combined thrust at liftoff of about 28.6 million newtons (6.5 million pounds) from its two solid rocket boosters and the three liquid-propellant main engines on the orbiter. Its top capacity into low Earth orbit will be 29,500 kilograms (65,000 pounds) in its fully operational configuration. This can consist of one large payload; a combination of up to three spacecraft with attached solid stages for injection into higher orbits, along with smaller packages that remain with the orbiter but must operate in the space environment; or a mixture of these types of payloads. The Space Shuttle will be the only American vehicle designed for manned spaceflight for the indefinite future.

MANNED SPACE FLIGHT COSTS*

Mercury Program.	$ 392,600,000
Gemini Program	1,283,400,000
Apollo Program.	25,000,000,000**
Skylab Program.	2,600,000,000
Apollo-Soyuz Test Project. . . . . (U.S. portion)	250,000,000

*Includes rockets, rocket engines, spacecraft, tracking and data acquisition, operations, operations support and facilities.

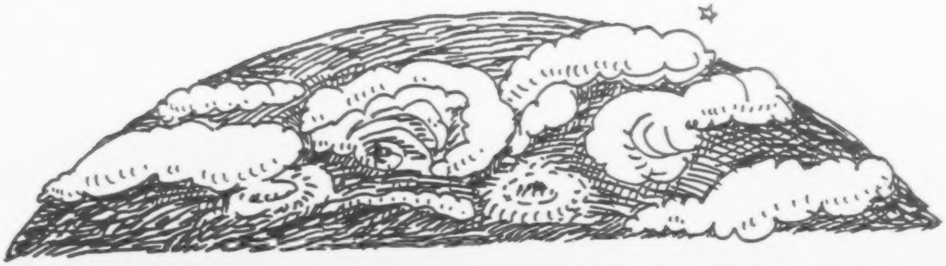
**Apollo mission cost range from $145 million for Apollo 7, the first manned Apollo mission, to $450 million for Apollo 17, the last flight in the program.

NASA
National Aeronautics and
Space Administration

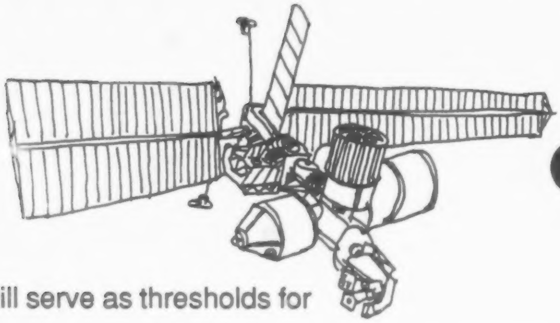
John F. Kennedy Space Center

space colonies

data



All You Need to Know for this Unit



Space stations will soon be part of your reality. They will serve as thresholds for further exploration of our solar system and other galaxies.

Actual space colonies have been seriously considered. Because of the threats of nuclear annihilation and the ecological unbalance generated by unchecked pollution, serious thought has been given to the creation of a space colony. In this module the only science which is required is provided by general statements about the limitations that will be encountered when building in space. Although it would be possible to place a colony within the earth's atmosphere, this is very unlikely. The first lesson examines the different layers of the earth's atmosphere in case someone decides that this is where he or she would like to build.

Basic Criteria for Building in Space

1. Because of the greatly reduced gravitational pull, toothpicks will be as strong as steel beams.
2. Unless you allow for rotation and place your colony close to a planet, you will have 24-hour days and no nights.
3. Without a gaseous atmosphere, the heat of the sun will be much more intense than on the earth if you remain at the same distance from the sun.
4. Gravity problems:
    a. Unless the colony rotates, there will be continuous weightlessness. Human muscles tend to atrophy in prolonged weightlessness, particularly the heart muscle.
    b. Without gravity, plant roots do not know which way to grow (although there has been some success growing plants on a shuttle mission).
    c. Producing gravity would require all or part of the space colony to rotate. The rotational speed and the diameter of the colony determine the amount of gravity. If the diameter of the colony were too small, it would have to spin at a tremendous speed producing a dizzying effect for the inhabitants. However, it may be necessary to duplicate the earth's gravity. This could lead to interesting options for the students.
    d. There are advantages to having weightlessness: ease of movement, new construction materials, new games, etc.
5. Problems that need to be addressed by the students are the following:
    - How and where will the colonists get their food?
    - How do they get the gasses necessary to breathe?
    - What do they do about their waste products?
    - How do they produce energy?

Students may design any type of colony or space station using one or all geometric solids. All that is necessary scientifically is that they make an attempt to address the questions posed above, not that their ideas provide workable solutions.

SPACE STATION

In a purely physical sense, the Space Station will overshadow all preceding space facilities. Although often referred to as the "NASA" Space Station, it will actually be international in character; Europe, Canada, and Japan, in particular, plan to develop their own hardware components for the Station. As currently visualized, the initial Station will be a 350-foot by 300-foot structure containing four pressurized modules (two for living and two for working), assorted attached pallets for experiments and manufacturing, eight large solar panels for power, communications and propulsion systems, and a robotic manipulator system similar to the shuttle arm. When fully assembled, the initial Station will weigh about 300,000 pounds and carry a crew of six, with a replacement crew brought on board every 90 days.

To deliver and assemble the Station's components, 12 shuttle flights will be required over an 18-month period. The pressurized modules used by the Station will be about 14 feet in diameter and 40 feet long to fit in the shuttle's cargo bay. The Station will circle Earth every 90 minutes at 250-mile altitude and 28.5 degree orbital inclination. Thus the Station will travel only between 28.5 degrees north and south latitudes. Unoccupied associate platforms that can be serviced by crews will be in orbits similar to this, as well as in polar orbits circling Earth over the North and South Poles. Polar-orbiting platforms will carry instruments for systems that require a view of the entire globe.

The Station will provide a versatile, multifunctional facility. In addition to providing housing, food, air, and water for its inhabitants, it will be a science laboratory performing scientific studies in astronomy, space plasma physics, Earth sciences (including the ocean and atmosphere), materials research and development, and life sciences. The Station will also be used to improve our space technology capability, including electrical power generation, robotics and automation, life support systems, Earth observation sensors, and communications.

The Station will provide a transportation hub for shuttle missions to and from Earth. When the crew is rotated every 90 days, the shuttle will deliver food and water from Earth, as well as materials and equipment for the science laboratories and manufacturing facilities. Finished products and experiment results will be returned to Earth. The Station will be the originating point and destination for flights to nearby platforms and other Earth orbits. The orbital maneuvering vehicle used for these trips will be docked at the Station.

The Station will be a service and repair depot for satellites and platforms orbiting in formation with it. Robotic manipulator arms, much like those on the shuttle, will position satellites in hangars or special docking fixtures. "Smart" repair and servicing robots will gradually replace astronauts in space suits for maintenance work, as satellites become more standardized and modular in design.

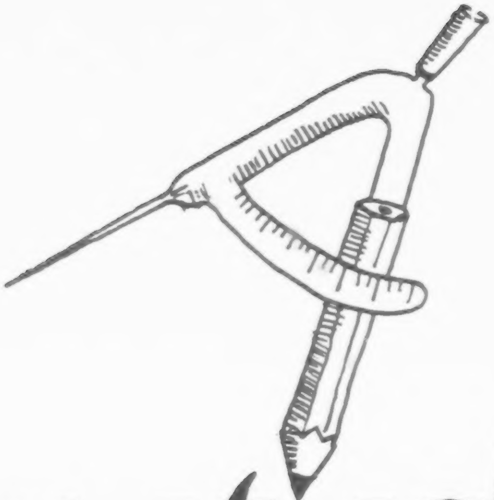
From: Pioneering the Space Frontier The Report of The National Commision on Space, Bantam Books, 1986.

SELF-REPLICATING FACTORIES IN SPACE

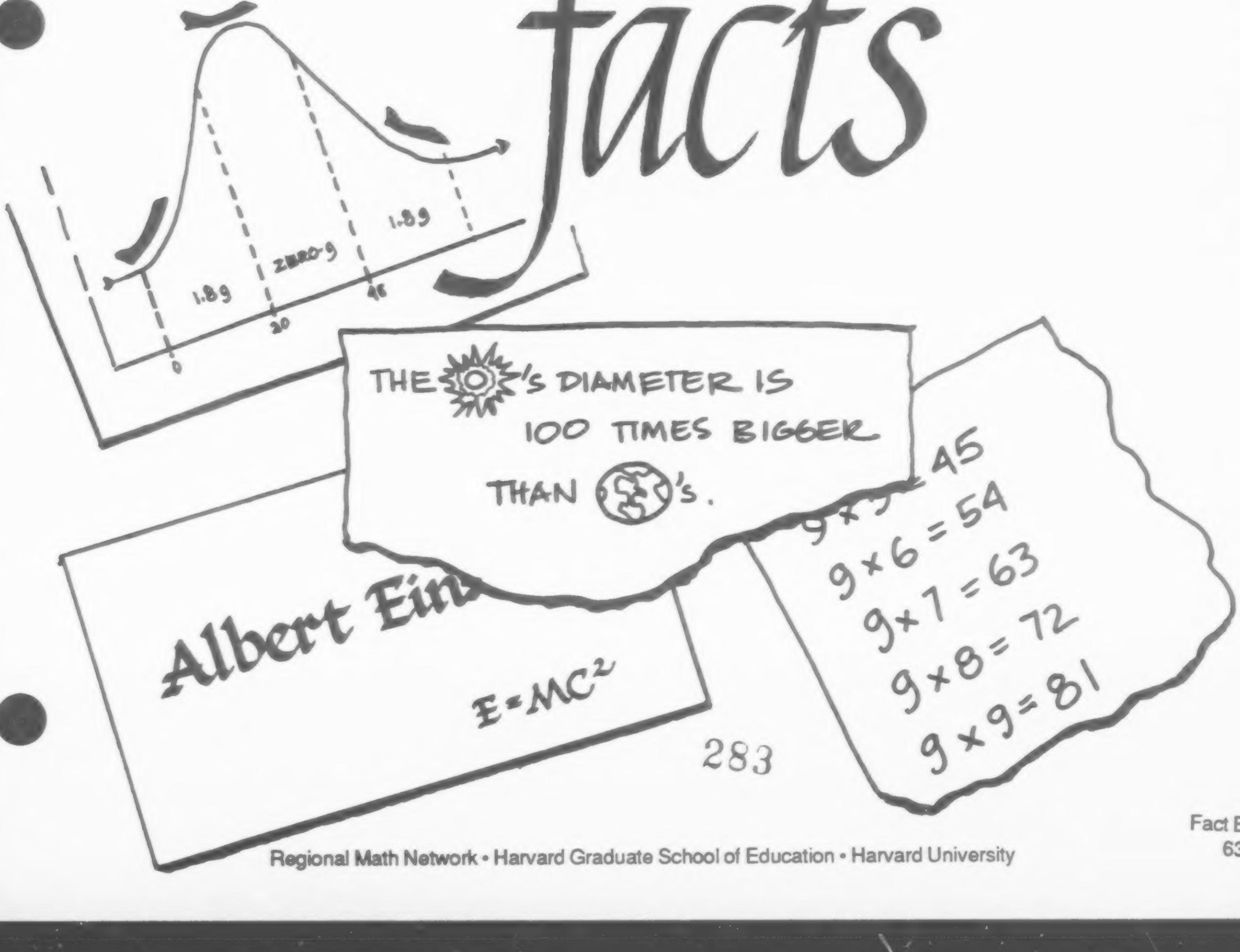
Factories that could replicate themselves would be attractive for application in space because the limited carrying capacity of our rocket vehicles and the high costs of space transport make it difficult otherwise to establish factories with large capacities. The concept of self-replicating factories was developed by the mathematician John von Neumann. Three components are needed for industrial establishment in space: a transporting machine, a plant to process raw material, and a "job shop" capable of making the heavy, simple parts of more transporting machines, process plants, and job shops. These three components would all be tele-operated from Earth, and would normally be maintained by robots. Intricate parts would be supplied from Earth, but would be only a small percentage of the total. Here is an example of how such components, once established, could grow from an initial "seed" exponentially, the same way that savings grow at compound interest, to become a large industrial establishment:

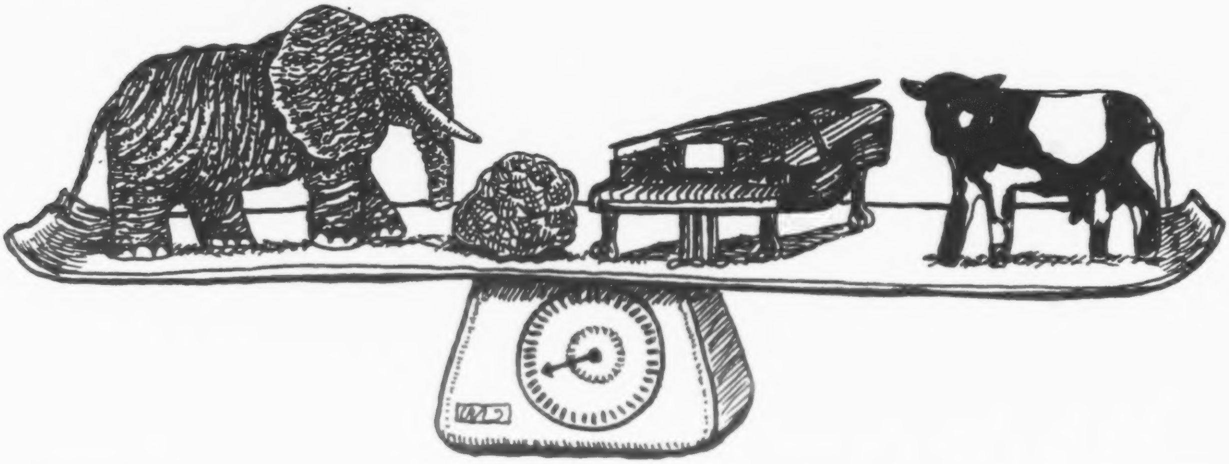
Suppose each of the three seed components had a mass of 10 tons, so that it could be transported to the Moon in one piece. The initial seed on the Moon would then be 30 tons. A processing plant and job shop would also be located in space—20 tons more. After the first replication, the total industrial capacity in space and on the Moon would be doubled, and after six more doublings it would be 128 times the capacity of the initial seed. Those seven doublings would give us the industrial capacity to transport, process, and fabricate finished products from over 100,000 tons of lunar material each year from then onward. That would be more than 2,000 times the weight of the initial seed—a high payback from our initial investment.

From: Pioneering the Space Frontier The Report of The National Commision on Space, Bantam Books, 1986.



mathematical facts





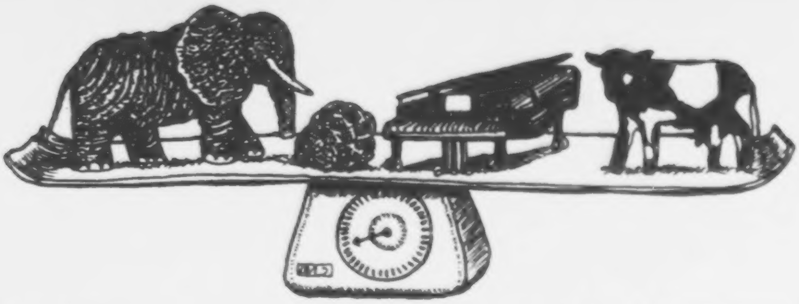
MEASUREMENT TRIVIA

WEIGHTS

Jumbo, the Tufts Elephant		8012	lb.
Bag of Potatoes		5	lb. or 10 lb.
Refrigerator Perry, Football Player		310	lb.
A Brick		4	lb.
A Piano		565	lb.
MBTA Bus - Empty		16	Tons
Volkswagon	Super	2072	lb.
	Sedan	1973	lb.
	Convertible	2127	lb.
Weight a Champion Weight Lifter	Can Bench Press	627	lb.
	Can Knee Lift	1200	lb.

HEIGHTS

Prudential		750	ft.
John Hancock		800	ft.
Upper Deck of Mystic River Bridge		16	ft.
Bunker Hill Monument		221	ft.
Mt. Washington		6288	ft.
Big Blue in the Blue Hills		610	ft.
Telephone Poll		17	ft.
Basketball Hoop		10	ft.
Doorway		6	ft. 6 inches
Manute Bol: Basketball Player		7	ft. 6 inches
Spud Webb: Basketball Player		5	ft. 7 inches
12 year old (on average)		4	ft. 10 inches
Teacher (on average):	Man	5	ft. 9 inches
	Woman	5	ft. 4 inches



MEASUREMENT TRIVIA

LENGTHS

Football Field	100	yds.
Knight Rider Transam	192	inches
Lincoln Continental	200.7	inches.
MBTA Bus	40	ft.
Family Swimming Pool	25	ft.
Olympic Swimming Pool	100	yds.
Bruin's Ice Rink	220	ft.
Boston Skating Club Ice Rink	193	ft.
Basketball Court	94	ft.
Concorde Jet	202	ft.

DISTANCES

Boston to Disneyland	1116	miles
Distance through Earth from One Pole to another	7927	miles
Boston to Chicago	498	miles

SPEEDS

Cross Country Skiing	5	m.p.h.
Running	6.5	m.p.h.
Swimming	40	yds./min.
Bicycling	10	m.p.h.
Walking	4	m.p.h.
Stagecoach	8	m.p.h.
Early Steam Locomotive (Stevenson's Rocket)	15	m.p.h.
Henry Ford's First Car: Model T	45	m.p.h.
Snowmobile	135	m.p.h.
Electric Train	200	m.p.h.
Jet	650	m.p.h.
Supersonic Transport (SST)	1450	m.p.h.
Speed of Light	186,000	m.p.h.
Speed of Sound (avg.)	738	m.p.h.
Maximum speed of Orbiter	25,780	m.p.h.
Orbital speed of Columbia	25,366	m.p.h.

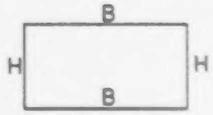
USEFUL FORMULAE

Geometric Shapes

Rectangles:

Perimeter: $P = 2H + 2B$

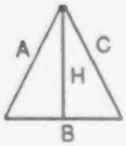
Area: $A = BH$



Triangles:

Perimeter: $P = A + B + C$

Area: $A = 1/2\ BH$

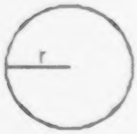


Circles:

Diameter: $D = 2r$

Circumference: $C = \pi D$

Area: $A = \pi r^2$



Tetrahedrons:

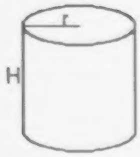
Surface Area: $SA = 2BH$

Volume: $V = 1/3$ (Area of Base) • Height

Cylinders:

Surface Area: $SA = 2\pi rH$

Volume: $V = \pi r^2 H$



Spheres:

Surface Area: $SA = 4\pi r$

Volume: $V = 4/3\ \pi r^3$

Constants:

$\pi \approx 22/7$ or 3.14

OTHER FORMULAE

Travel:

Distance: $D = RT$

Rate: $R = D/T$

Time: $T = D/R$

D = Distance
R = Rate (Speed)
T = Time

Gravity:

Force of Gravity Between Two Objects

$$F = \frac{G \cdot M_1 \cdot M_2}{D^2}$$

G = Gravity Constant
M_1 = Mass of first object
M_2 = Mass of second object
D = Distance between the objects

g's Pulled in Centrifugal Force:

$$g's = \frac{4D}{T^2}$$

D = Distance from center
T = Turning period
(Time it takes to make a complete turn)

Thrust:

Thrust is a type of Force
Force = Mass • Acceleration

MATHEMATICAL CONVERSIONS

1 FOOT = 12 INCHES
1 YARD = 3 FEET
1 MILE = 5280 FEET

1 MINUTE = 60 SECONDS
I HOUR = 60 MINUTES
1 DAY = 24 HOURS
1 YEAR = 365 DAYS

1 CUP = 8 OUNCES
1 TON = 2000 POUNDS

COMPARISON OF ENGLISH AND METRIC MEASURES

1 INCH = 2.54 CENTIMETERS
1 FOOT = 0.305 METERS
1 YARD = 0.914 METERS
1 MILE = 1.609 KILOMETERS

1 OUNCE = 29.573 MILLILITERS
1 LIQUID QUART = 0.946 LITERS
1 GALLON = 3.785 LITERS

ABBREVIATIONS

INCH : IN.
FOOT : FT.
YARD : YD.
MILE : MI.
MINUTE : MIN.
HOUR : HR.

YEAR : YR.
CUP : C.
POUND : LB.
TON : T.
QUART : QT.
GALLON : GAL.

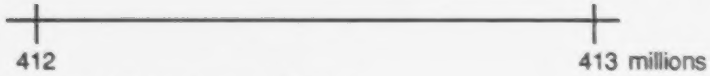
MILLIMETER: MM.
CENTIMETER : CM.
METER : M.
KILOMETER : KM.
LITER : L.

HOW TO ROUND

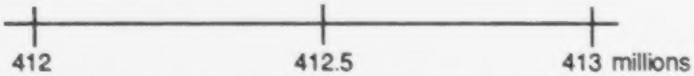
Perceptual Technique: The Number Line

- Round the number 412,316,752 to the millions.
- Draw a part of the number line, marking the appropriate end points. The end points are determined by the place to which you intend to round, by considering consecutive multiples of the rounding place.

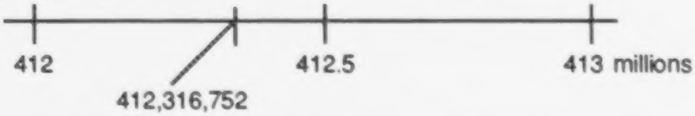
- In this case you are rounding to millions. The consecutive multiples of millions are 412 million and 413 million.



- Mark the half-way point between them.



- Estimate the original number on the number line.



- Round the original number to the endpoint which is closer.

Verbal "Recipe":

- Mark the place to which the number is to be rounded with a circle (in this case the millions). Draw an arrow over the following place.

41②316,752

- Change arrow-marked digit, and all digits to its right to zeroes: 412,000,000

- Look at the original number. If the arrow-marked digit is 5 or more, increase the circled digit by 1. If the arrow-marked digit is less than 5, leave the circled digit unchanged.

Thus, 412,000,000 is the number rounded to the millions place.

Writing numerals in rounded form:

- Point out to students that you could write: 412,316,752 rounded as the rounded numeral 412,000,000 or 412 million.

CALCULATING USING ROUNDED NUMBERS

Addition

Problem: "What planet is about 50 million miles farther from the sun than the Earth is?

Procedure:

Gather data: Distance from unknown planet to the sun = D
Distance from Earth to the sun = 92,963,115 mi.

Think: D = 50,000,000 mi. + 92,963,115 mi.

Change to rounded numerals:
D ~ 50,000,000 mi. + 92,000,000 mi.
D ~ 142,000,000 mi.

Solution: Mars is 141,642,351 mi. from the sun. Rounding to millions, Mars is 142,000,000 mi. from the sun.

Subtraction

Problem: What is the difference between the diameter of Venus and the diameter of Jupiter?

Procedure:

Gather data: Difference in diameter = D
Diameter of Venus = 88,733 mi.
Diameter of Jupiter = 7,521 mi.

Think: D = 88,733 mi. - 7,521 mi.

Change to rounded numerals:
D ~ 89,000 mi. - 8,000 mi.
D ~ 81,000 mi.

Solution: The difference in diameter between Venus and Jupiter is about 81,000 mi.

CALCULATING USING ROUNDED NUMERALS

Multiplication

Problem: Calculate the distance around the Earth at the equator.

Procedure:

Gather data: Distance around can be thought of as the circumference of the Earth's Great Circle (C).
Diameter of Earth = 7,921 mi.

Think:
$C = \pi D$
$C = \pi (7921 \text{ mi.})$

Change to rounded numerals:
$C \sim 3.14(8000 \text{ mi.})$
$C \sim 3(8000 \text{ mi.})$
$C \sim 24,000 \text{ mi.}$

Solution: The distance around the Earth at the diameter is about 24,00 miles.

Division

Problem: The distance around a particular planet is 234,143 miles.
What is the approximate diameter of the planet?
Which planet is it?

Procedure:

Gather data: Distance around planet = 234,143 mi.

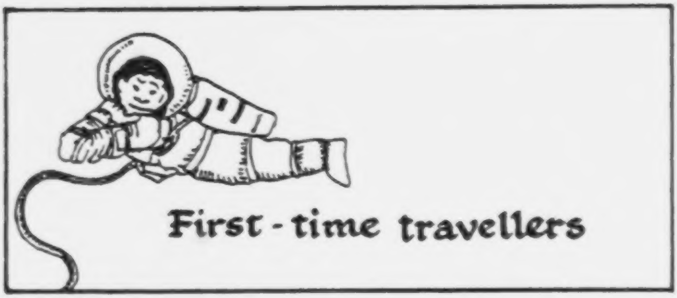
Think: Distance around can be thought of as the circumference at the planet's Great Circle. (C)
$C = \pi D$
$234,143 \text{ mi} = \pi D$

Change to rounded numerals:
$200,000 \text{ mi} \sim 3.14D$
$200,000 \text{ mi} \sim 3D$
$\frac{200,000 \text{ mi}}{3} \sim D$
$70,000 \text{ mi} \sim D$

Solution: The diameter of the unknown planet is about 70,000 miles. The diameter ofSaturn is 74,607 miles. Rounding to the tens of thousands, Saturn's diameter is about 70,000 miles.

Math/Space Mission

Problem Deck



First-time travellers

Professional Astronauts

Expert Crews

Regional Math Network • Harvard Graduate School of Education • Harvard University

Math/Space Mission
Problem Deck
Summary of Cards

CARD NO.	ACTIVITY	MATH TOPIC TO WHICH ESTIMATION IS APPLIED	LEVEL OF DIFFICULTY
1	Let's Communicate with Pluto	Using Formulae	Challenge
2	Comparing the Volume and Mass of Earth & Moon	Ratio Using Formulae	Challenge
3	Jupiter's Moons	Rounding and Comparing	Practice
4	More of Jupiter's Moons	Rounding and Comparing	Practice
5	"Three for Three"	Computation	Moderate
6	Are You an Expert?	Computation	Moderate
7	Hands Around the World	Circumference Calculation	Moderate
8	Robots Around the Moon	Circumference	Moderate
9	Travelling in the Solar System... From the Minute You Were Born	Using Formulae: D=RT	Challenge
10	Passing the Planets, "How Old Am I Now?"	Using Formulae: D=RT	Challenge
11	90% of the Solar System?	Computation, Percent	Practice
12	Lining up the Planets	Least Common Multiple	Moderate

SUPPOSE THERE WERE SOMEONE OR SOMETHING ON PLUTO TRYING TO COMMUNICATE WITH US!

YOU SEND A MESSAGE TODAY.
THE MESSAGE WILL TRAVEL AT THE SPEED OF LIGHT.

HOW LONG WILL IT TAKE FOR THE MESSAGE TO GET TO PLUTO?

Problem Card 1

THE AVERAGE RADIUS OF EARTH IS 3963 MILES.
THE AVERAGE RADIUS OF THE MOON IS 1080 MILES.

WHAT IS THE RATIO OF THE VOLUME OF THE EARTH TO THE VOLUME OF THE MOON?

WHAT IS THE RATIO OF THE MASS OF THE EARTH TO THE MASS OF THE MOON?

(VOLUME = $4/3 \cdot \pi \cdot (\text{RADIUS})^3$)

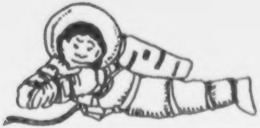
WHAT DO YOU THINK EXPLAINS THE DIFFERENCE IN THESE ANSWERS?

Problem Card 2

JUPITER IS THE LARGEST PLANET OF OUR SOLAR SYSTEM AND IT ALSO HAS THE MOST "MOONS". THE PIONEER AND VOYAGER MISSIONS CONFIRMED JUPITER HAS 16 SATELLITES. SOME ARE QUITE SMALL IN DIAMETER AND OTHERS ARE VERY LARGE.

- JUPITER'S SATELLITE ELARA IS 12,895,000 MILES FROM JUPITER. WRITE THE DISTANCE IN WORDS.
- HIMALIA IS APPROXIMATELY SEVEN MILLION ONE HUNDRED THIRTY THOUSAND MILES FROM JUPITER. WRITE THE DISTANCE IN NUMERALS.
- PASIPHAE IS ABOUT 14,500,000 MILES FROM JUPITER. SINOPE IS APPROXIMATELY TWO HUNDRED THOUSAND MILES FURTHER FROM JUPITER. HOW FAR IS SINOPE FROM JUPITER IN MILLIONS OF MILES?

Problem Card 3



SATELLITE OF JUPITER	DISTANCE FROM JUPITER	SATELLITE OF JUPITER	DISTANCE FROM JUPITER
CALLISTO	1,170,130 MILES	LYSITHEA	7,280,003 MILES
EUROPA	417,009 MILES	CARME	13,894,700 MILES
ELARA	7,301,303 MILES	PASIPHAE	14,500,000 MILES
GANYMEDE	665,112 MILES	LEDA	6,891,013 MILES

- LIST THESE SATELLITES IN THE ORDER OF THEIR DISTANCES FROM JUPITER, FROM CLOSEST TO FARTHEST.

- ROUND THE DISTANCE FOR EACH SATELLITE FROM JUPITER TO THE NEAREST MILLION MILES.

SOLVE THESE PROBLEMS ABOUT JUPITER'S MOONS

CALLISTO IS 1,170,000 MILES FROM JUPITER. THEBE IS APPROXIMATELY 55,000 MILES LESS THAN ONE-SIXTH OF CALLISTO'S DISTANCE FROM JUPITER. HOW FAR IS THEBE FROM JUPITER?

THE SATELLITE 1979 J3 IS 127,600 KM FROM JUPITER. ONE KILOMETER IS APPROXIMATELY 0.62 MILES. HOW FAR IS 1979 J3 FROM JUPITER IN MILES?

Problem Card 5

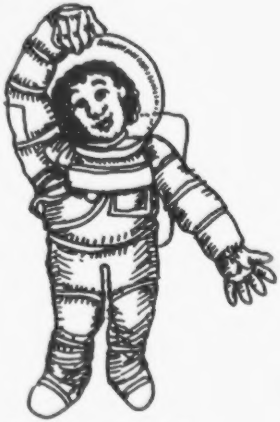
THEBE HAS A DIAMETER OF 47 MILES AND CALLISTO HAS A DIAMETER OF 2,996 MILES. APPROXIMATELY HOW MANY TIMES SMALLER IS THEBE THAN CALLISTO?

Io'S DISTANCE IN KILOMETERS CAN BE FOUND BY USING THE FOLLOWING CLUES.

A) THE THOUSANDS DIGIT IS ONE-HALF THE TEN-THOUSANDS DIGIT.
B) THE HUNDRED-THOUSAND DIGIT IS TWICE THE TEN-THOUSANDS DIGIT.
C) THE HUNDREDS DIGIT IS THE SUM OF THE DIGITS IN THE TEN-THOUSAND AND HUNDRED-THOUSAND PLACES.
D) THE SUM OF THE DIGITS IS 13.
E) ASSUME ALL OTHER DIGITS ARE ZERO.

Problem Card 6

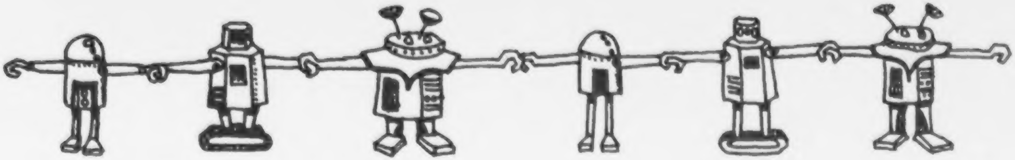
IMAGINE "HANDS ACROSS AMERICA" WERE EXTENDED TO "HANDS AROUND THE WORLD." HOW MANY PEOPLE STRETCHING THEIR ARMS WOULD IT TAKE TO GO AROUND THE EARTH AT THE EQUATOR?



CIRCUMFERENCE OF A CIRCLE = π * DIAMETER.
ASSUME THE AVERAGE REACH IS 5 FEET,
FROM FINGER TIP TO FINGER TIP.

Problem Card 7

Regional Math Network • Harvard Graduate School of Education • Harvard University

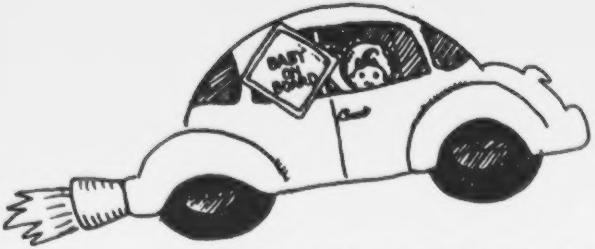


IF "HANDS ACROSS AMERICA" WERE EXTENDED TO
"ROBOTS AROUND THE MOON,"
HOW MANY ROBOTS WOULD IT TAKE TO GO AROUND THE
MOON AT ITS "EQUATOR"?

CIRCUMFERENCE = π * DIAMETER
ASSUME A ROBOT'S REACH IS 3 FEET,
FROM "ROBOT'S PROBE-TIP" TO "ROBOT'S PROBE-TIP."

Problem Card 8

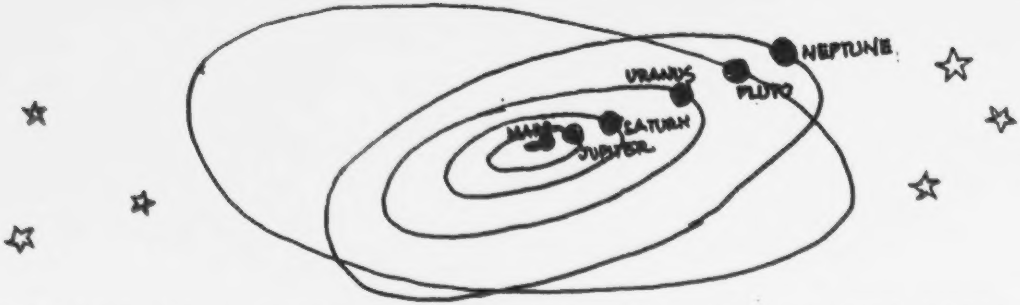
Regional Math Network • Harvard Graduate School of Education • Harvard University



HOW FAR IN THE SOLAR SYSTEM WOULD YOU HAVE TRAVELLED,
IF YOU STARTED THE YEAR YOU WERE BORN
AND WERE TRAVELLING IN YOUR VW AT 55 MPH?

HOW FAR IN THE SOLAR SYSTEM WOULD YOU HAVE TRAVELLED,
IF YOU STARTED THE YEAR YOU WERE BORN
AND WERE TRAVELLING IN THE SHUTTLE AT ABOUT 17,500 MPH?
(ASSUMING YOU TRAVEL IN A STRAIGHT LINE.)

Problem Card 9



ASSUME THE OUTER PLANETS, JUPITER, SATURN, MARS, URANUS, PLUTO AND NEPTUNE FORM A STRAIGHT LINE FROM THE SUN AS THEY DO NOW.

YOU ARE TRAVELLING ON A SATURN ROCKET, AT 25,000 MPH. HOW OLD WOULD YOU BE AS YOU PASSED EACH PLANET?

Problem Card 10

TWO PLANETS OF THE SOLAR SYSTEM ACCOUNT FOR MORE THAN 90% OF THE TOTAL PLANETARY MASS OF THE SOLAR SYSTEM.

WHICH TWO PLANETS ARE THEY?

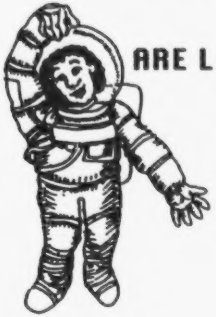
SHOW THAT THEY ACCOUNT FOR MORE THEN 90% OF THE TOTAL MASS.

Problem Card 11

Regional Math Network • Harvard Graduate School of Education • Harvard University

THE PLANETS EARTH, JUPITER, SATURN AND URANUS
REVOLVE AROUND THE SUN
APPROXIMATELY ONCE EVERY 1, 12, 30 AND 84 YEARS RESPECTIVELY.

IF THEY ARE LINED UP NOW, WHEN WILL THIS HAPPEN AGAIN?

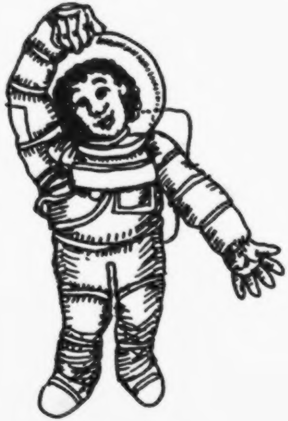


IF THE PLANETS JUPITER, SATURN AND URANUS
ARE LINED UP NOW, HOW LONG WILL IT BE UNTIL THIS HAPPENS AGAIN?

Problem Card 12

Regional Math Network • Harvard Graduate School of Education • Harvard University

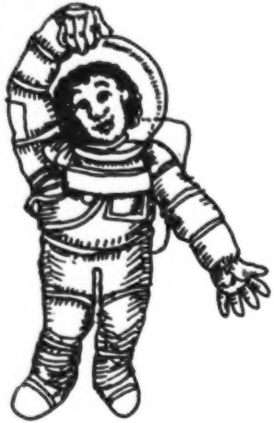
IF THE HEIGHT OF THE PRUDENTIAL BUILDING REPRESENTS THE DIAMETER OF THE EARTH, WHAT CAN YOU FIND IN OUR CITY TO REPRESENT THE DIAMETERS OF THE MOON AND THE SUN?



Problem Card 13

Regional Math Network • Harvard Graduate School of Education • Harvard University

ONCE IN ORBIT, HOW LONG DOES IT TAKE THE ORBITER
TO TRAVEL FROM KENNEDY SPACE CENTER (FLORIDA)
UNTIL IT IS OVER PARIS?
THE ORBITER IS TRAVELLING FROM WEST TO EAST.
(IGNORE HEIGHT ABOVE EARTH.)



Problem Card 14

ARE YOU SWELL HEADED?

COMPARE THE DISTANCE AROUND YOUR HEAD
TO THE DISTANCE AROUND THE EARTH.
MEASURE THE DISTANCE AROUND
YOUR HEAD WITH A STRING.
FIND THE DISTANCE AROUND THE EARTH AT THE EQUATOR.

CIRCUMFERENCE = π * DIAMETER

HOW MANY TIMES BIGGER IS THE DISTANCE
AROUND THE EARTH THAN THE
DISTANCE AROUND YOUR HEAD?

Problem Card 15

Regional Math Network • Harvard Graduate School of Education • Harvard University

**HOW LONG WOULD IT TAKE TO TRAVEL TO NEPTUNE FROM EARTH,
IF YOU TRAVELLED ON THE
FASTEST KNOWN SPACE VEHICLE?**

The fastest known space vehicle was the US-German orbiter.
Its speed was 149,125 mph.

Problem Card 16

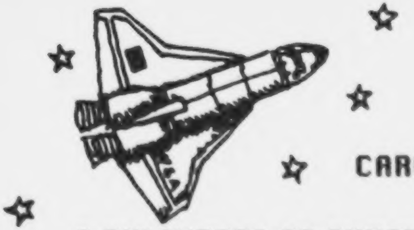
Regional Math Network • Harvard Graduate School of Education • Harvard University

THE DISTANCES IN THE UNIVERSE ARE SO GREAT THAT SCIENTISTS USE LIGHT YEARS TO MEASURE THEM.

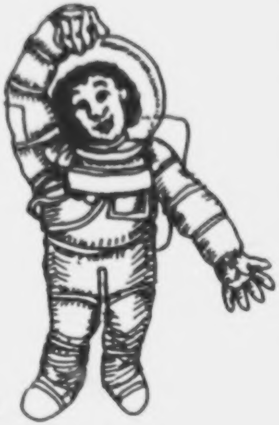
A LIGHT YEAR IS THE DISTANCE LIGHT CAN TRAVEL IN ONE YEAR.

THE NEAREST KNOWN STAR IN MORE THAN 4 LIGHT YEARS AWAY FROM THE EARTH. HOW FAR AWAY IS IT?

Problem Card 17



CARGO ORDER FOR NEXT SHUTTLE MISSION



6 CYLINDERS OF OXYGEN: 6' IN DIAMETER AND 10' LONG EACH

4 CARTONS OF TANG: 4' X 8' X 3' EACH

2 SUITCASES OF MAGAZINES: 2' X 4' X 1.5' EACH

WHAT IS THE VOLUME OF THIS CARGO IN CUBIC FEET?

AT A COST OF $2000 PER CUBIC FOOT, THE COST WOULD BE ________?

IF YOU LEAVE EARTH AND RETURN TO EARTH,
COULD YOU VISIT EACH AND EVERY PLANET ONCE AND ONLY ONCE,
ASSUMING YOU CAN TRAVEL NO MORE THAN 25 BILLION MILES?

WHAT WOULD BE YOUR ROUTE?

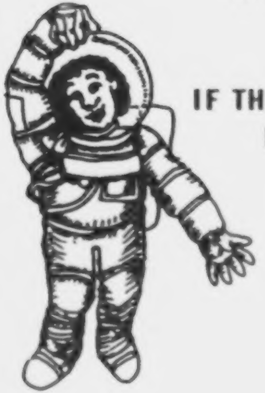
WHAT ASSUMPTIONS MUST YOU MAKE TO SOLVE THIS PUZZLE?

Problem Card 19

Regional Math Network • Harvard Graduate School of Education • Harvard University

SUPPOSE THE ORBITER, ONCE IN ORBIT,
PASSES DIRECTLY OVER THE PRUDENTIAL BUILDING.

THE ORBITER WILL BE TRAVELLING AT
A HEIGHT OF APPROXIMATELY 600 MILES AND IN THE
SAME DIRECTION AS THE EARTH'S ROTATION.



IF THE ORBITER CONTINUES IN THE SAME ORBIT, HOW LONG
BEFORE IT PASSES OVER THE PRUDENTIAL AGAIN?

Problem Card 20

Regional Math Network • Harvard Graduate School of Education • Harvard University

THE SPEED OF LIGHT IS ABOUT 186,000 MILES PER SECOND.

A LIGHT YEAR IS THE DISTANCE LIGHT CAN TRAVEL IN 1 YEAR.
CALCULATE THE NUMBER OF MILES IN 1 LIGHT YEAR.

CALCULATE THE SPEED OF LIGHT IN MILES PER HOUR.

Problem Card 21

Regional Math Network • Harvard Graduate School of Education • Harvard University

A FICTITIOUS PUZZLE!

ROBERT CRIPPEN, NORMAN THAGARD AND FREDERICK HAUCK
WERE CREW MEMBERS OF THE STS #7 MISSION WITH SALLY RIDE.

ONE CREW MEMBER WAS THE COMMANDER,
ONE THE MISSION SPECIALIST, AND
ONE THE PILOT.

THE MISSION SPECIALIST, AND ONLY CHILD,
HAS FLOWN THE LEAST NUMBER OF YEARS.
FRED HAUCK, WHO MARRIED ROBERT CRIPPEN'S SISTER,
HAS FLOWN MORE MISSIONS THAN THE COMMANDER.

MATCH THE CREW MEMBERS TO THEIR JOBS.

Problem Card 22

MORE INTERPLANETARY TRAVEL PLANS

USING 25 BILLION MILES, WHAT IS THE MAXIMUM NUMBER OF PLANETS YOU COULD VISIT, ASSUMING YOU LEAVE EARTH AND RETURN TO EARTH?

WHAT ASSUMPTIONS MUST YOU MAKE TO SOLVE THIS PUZZLE?

Problem Card 23

SUPPOSE 21 ASTRONAUTS ARE AVAILABLE
FOR A LUNAR LANDING MISSION.
12 ASTRONAUTS HAVE HAD ORBITAL EXPERIENCE.

HOW MANY DIFFERENT CREWS OF 3 CAN BE MADE UP?

HOW MANY OF THESE CREWS WOULD HAVE AT LEAST
ONE ASTRONAUT WHO HAS HAD ORBITAL EXPERIENCE?

Problem Card 24

Regional Math Network • Harvard Graduate School of Education • Harvard University

ABOUT 6,695,520 SQUARE MILES OF THE EARTH'S SURFACE IS LAND. ABOUT HOW MUCH OF THE EARTH'S SURFACE IS NOT LAND?

WHAT IS THE RATIO OF EARTH'S LAND SURFACE TO ITS WATER SURFACE?

Problem Card 25

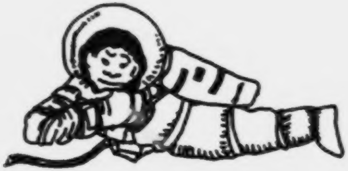
IF A MAN WEIGHS 180 POUNDS ON EARTH,
WHAT WOULD HE WEIGH ON THE MOON?

DUE TO THE DIFFERENCES IN GRAVITY, ONE'S WEIGHT ON THE MOON IS ONE SIXTH OF ONE'S WEIGHT ON EARTH.

WHAT WOULD YOU WEIGH ON THE MOON?
...ON VENUS?
...ON MARS?

Problem Card 26

A WORLD CHAMPION WEIGHT LIFTER CAN LIFT 1200 POUNDS ON EARTH. IF HE WERE ON THE MOON AND WERE ABLE TO EXERT THE SAME LIFTING FORCE, HOW MANY POUNDS COULD HE LIFT?



Problem Card 27

Summary of Facts for Planets, Moon & Sun

	MERC.	VENUS	EARTH	MOON	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO	SUN
Average Distance from Sun (Miles)	36,000,000	67,200,000	92,900,000	238,900 from earth	141,515,000	483,500,000	886,000,000	1,782,000,000	2,794,000,000	3,674,000,000	25 million to nearest star
Length of Year (Period of Orbit)	88.0 days	224.7 days	365.26 days	27.32 days	1.88 Years	11.86 Years	29.46 Years	84.01 Years	164.8 Years	247.7 Years	246 million to next galaxy
Length of Day (Period of Rotation)	58 days	243 days	24 hours	27 days	24 hours	9 hours	10 hours	15 hours	18 hours	6 days	25 days
Average Orbital Speed (MPH)	107,300	78,500	66,500	2,300	54,100	29,300	21,600	15,300	12,200	10,600	5[illegible]00 around galactic center
Equatorial Diameter (Miles)	3031	7521	7927	2160	4197	88,733	74[illegible]	31,600	30,200	2,113	865,000
Mass (Tons)	3.53×10^{20}	5.34×10^{21}	6.59×10^{21}	8.24×10^{19}	7.08×10^{20}	2.09×10^{24}	6.26×10^{23}	9.55×10^{22}	1.15×10^{23}	1.12×10^{19}	2.19×10^{27}
Escape Velocity (MPH)	9,619	23,042	25,055	5,324	11,185	141,828	88,139	48,096	54,136	751	1,378,000
Temperature Max °F	660	896	136.4	225	80	53,500	*	*	*	-382	27,000,000
Min °F	-270	-27	-126.9	-243	-190	-140	-292	-346	-364	-390	10,800
# Moons	0	0	1	-	2	16+rings	23?+rings	5+rings	2	1	9 planets
Eccentricity of Orbit	0.206	0.007	0.017	0.055	0.093	0.048	0.056	0.047	0.009	0.250	—
Surface Gravity	.38	.90	1	.16	.38	2.6	1.2	.93	1.4	0.03?	27.8

* Scientists do not yet know.

USEFUL DATA FOR SPACE MISSION PROBLEM DECK

Speed of Light: 186,000 Miles per Second
Speed of Orbiter in Orbit: 17,500 MPH
Speed of Fastest Known Space Vehicle: 149,125 MPH

Approximate Distance from Kennedy Space Center to Paris: 5035 MI.

Height of Bunker Hill Monument : 221 FT.
Height of Prudential Building: 750 FT.
Height of John Hancock Building: 780 FT.
Height of Big Blue in the Blue Hills: 610 FT.
Height of Mount Washington: 6,288 FT.
Height of Mount Everest: 29, 141 FT.

Regional Math Network • Harvard Graduate School of Education • Harvard University